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TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY

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Founded by LOUIS A. BAUER
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With the Cooperation of Eminent Investigators

CONTENTS

(*Contents concluded over*)

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CONTENTS—Concluded

GEORG HARTMANN
(Reproduced from a medallion portrait, courtesy of the British Museum)

Terrestrial Magnetism
and
Atmospheric Electricity

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SOME EARLY CONTRIBUTIONS TO THE HISTORY OF GEOMAGNETISM—IV

By H. D. Harradon

Georg Hartmann—On March 4, 1544, Georg Hartmann, Vicar of the St. Sebaldus at Nuremberg, addressed a letter to Duke Albrecht of Prussia in which he announced his discovery of the magnetic inclination and the first determination of the magnetic declination on land. We reproduce here (page 129) Hellmann's facsimile of the first page of the original of the letter which is in the Kgl. Staatsarchiv in Königsburg. This letter has been printed several times; first by J. Voigt in Raumers Historisches Taschenbuch, II (1831), then by H. W. Dove in Repertorium der Physik, II (1838), and later again by J. Voigt, together with other letters by Georg Hartmann in "Briefwechsel der berühmtesten Gelehrten des Zeitalters der Reformation mit Herzog Albrecht von Preussen" (Königsburg, 1841).

Since this important letter lay buried and unnoticed in the archives at Königsburg until the year 1831, it could not of course have exerted any influence previously on the science of geomagnetism. For this reason the discovery of the magnetic inclination is generally attributed to Robert Norman who first in 1576 determined the value of that element at London, as 71° 50′. One can hardly doubt from an examination of the text of Hartmann's letter that he discovered the phenomenon of the inclination. That his determination proved to be exceptionally inaccurate—about 9° instead of about 65°—may be explained by the fact that his magnetic needle was suspended on a vertical and not a horizontal pivot and hence was impeded in its inclining movement.

The letter, moreover, contains the announcement of the earliest determination of the magnetic declination on land. It was made at Rome, probably about the year 1510.[1]

[1]Hellmann fixes the year 1510 for the date of this determination of the declination by Hartmann in the following manner: "Die Beobachtung Hartmann's in Rom dürfte ums Jahr 1510 gemacht sein, da wir einerseits von ihm wissen (siehe Doppelmayr, Nachricht von den Nürnbergischen Mathematicis und Künstlern, S. 57) dass er nur zwischen 1510 und 1518 in Italien gelebt haben kann, und anderseits bekannt ist, dass Herzog Albrecht von Preussen von 1508 bis 1510 in Italien weilte. Jedenfalls beruht die Annahme Ciro Chistoni's (Misure assolute degli elementi del magnetismo terrestre fatte in Roma, Annali del Ufficio centrale meteorologico, vol. VIII, parte I, 1886, Roma, 1889), dem auch F. Denza (Pubblicazioni della Specola Vaticana, vol. III, S. 113) gefolgt ist, dass die Hartmann'sche Beobachtung erst 1543 gemacht worden sei, auf einem Irrtum bzw. auf einer Verwechselung mit dem Datum des Brifes von Hartmann an den Herzog Albrecht von Preussen. [Die Anfänge der magnetischen Beobachtungen, Zs. Ges. Erdk., Berlin, **32**, 112-136 (1897).]

We are indebted to Hellmann for the greater part of the information given above. The translation of the letter which follows was kindly furnished by Prof. Sydney Chapman of London.

THE LETTER OF GEORG HARTMANN TO DUKE ALBRECHT OF PRUSSIA

Praise the Lord, 4 March 1544, Nuremberg.

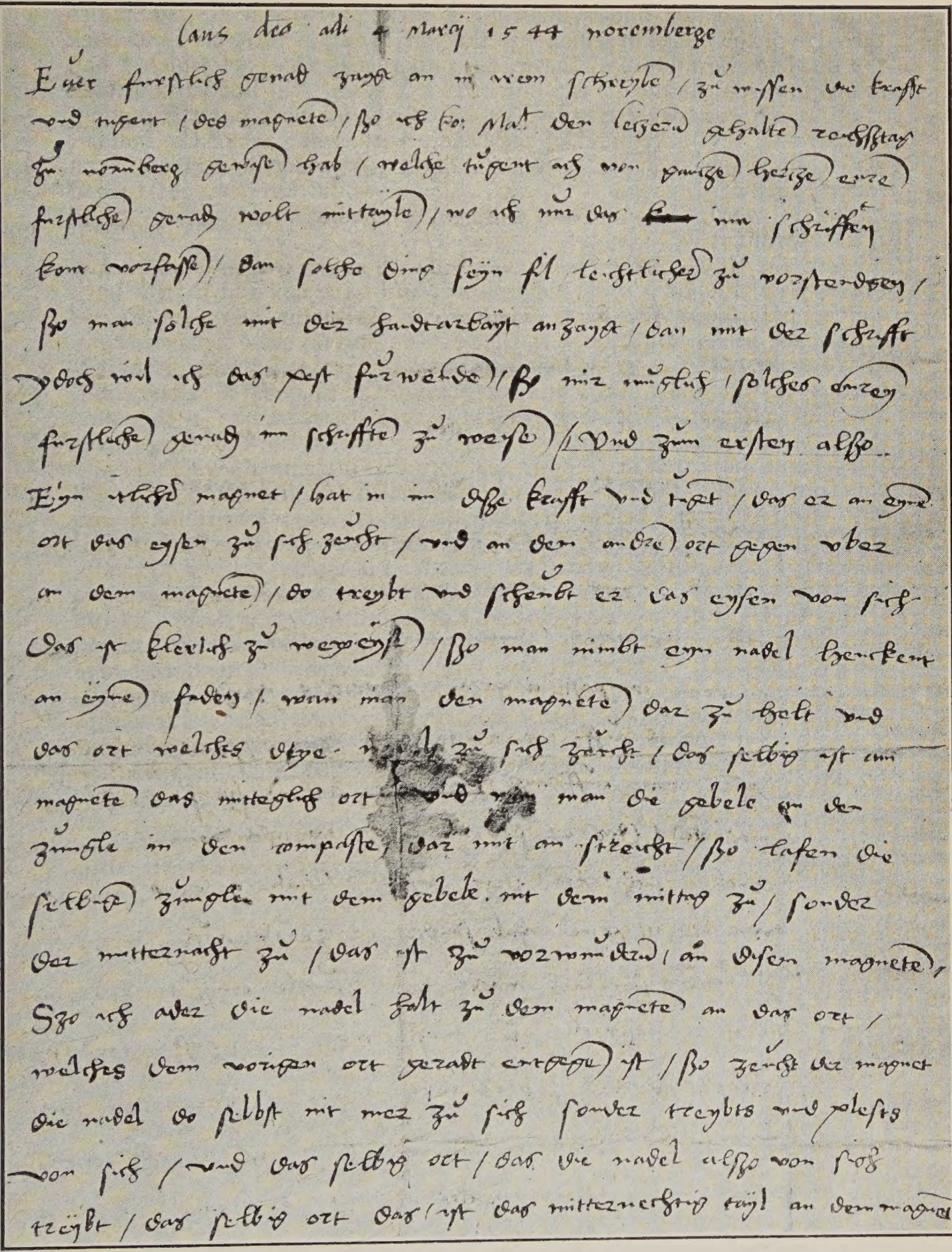
Your Grace writes wishing to know the power and virtue of the magnet as I showed them to his Majesty at the last sitting of the Reichstag in Nuremberg. This virtue I would right gladly explain to your Grace, as far as can be done by writing, for such things are more easily shown by handling than by letter. But I will do my very best to show it to your Grace in writing.

And first then: Every magnet has in it this power and virtue, that one part draws iron to it, and the part at the opposite end of the magnet pushes and drives iron away. This is clearly shown if one takes a needle hanging on a thread, and holds a magnet to it. And the part that draws the needle to itself is the south part of the magnet; and if one strokes the forked end of a compass needle with that part, then this needle turns with the forked end not to the south, but to the north. This is a wonder of the magnet. Now if I hold the needle to the opposite part of the magnet, the magnet no longer draws the needle to it, but drives and blows it away; and this part of the magnet, that thus drives the needle away, is the north part, and if one strokes the forked end of the needle with it, the needle then turns not north but south. But the magnet-stone is still more wonderful in that the needle stroked by it does not point due north, but turns away from the true south-north line and points eastwards, in some countries by 6°,* as I myself have found and studied, at the time in Rome, when his princely Grace, Margrave Gumprecht, and his brother were there together, but here in Nuremberg I find that this deviation is 10°, and in other places more or less. This is also always shown in compasses by a black mark under the glass, which mark, as one sees, always points not due north, but is away on the eastern side.

And secondly, I also find this about the magnet, that it not only turns from the north and deviates towards the east, by 9° more or less, as I have said, but also it dips downwards. This is now to be proved. I make a needle a finger's length, that stands level on a pointed rod, or level with a water-surface, so that it in no way inclines earthward, but both ends stand level in exact balance; but when I once stroke its ends, no matter which, then the needle no longer stands level, but dips downwards by 9° more or less. The cause why this happens I could not explain to His Majesty.

And thirdly, I have shown His Majesty how to find which part of the magnet is the south part, and which the north part. And thus I showed it to His Majesty. I had brought to me a large vessel full of water; and I had a fine small wooden bowl, that I set to swim in the middle of the water, and laid the magnet gently in the bowl. Now while I did not know which was the north part of the magnet, the bowl turns right

*Hellmann states that this observation, which was made in 1510 or thereabouts, is the first recorded measurement of the magnetic declination on land.



Laus deo adi 4 Marcij 1544 Noremberge
Euer fürstlich genad zayg an mit mein schreyben / zu wissen die krafft
und tugent / des magnetes / so ich bei Mat. den leczten gehalten reichstag
zu Nurnberg geredt hab / welche tugent auff mein geringe heilige erste
fürstliche genad wolt mittayln / wo ich mit der im schreiben
kom mochte / dan solche ding seyn fil leichtlicher zu verstenden /
so man solche mit der handtarbayt anzaygt / dan mit der schrifft
yedoch wil ich das pest furwenden / so mir muglich / solcher dingen
fürstliche genad im schrifft zu weysen / Und zum ersten also.
Eyn yeglicher magnet / hat in im dise krafft und tugent / das er an eynem
ort das eysen zu sich zeucht / und an dem andern ort gegen uber
an dem magnete / do treybt und schenckt er das eysen von sich
das ist klerlich zu weyssen / so man nimbt eyn nadel herczen
an eynem faden / wann man den magnete das zu helt und
das ort welchs [illegible] zu sich zeucht / das selbig ist am
magnete das mittegliche ort / und wan man die gabele an den
zungle in dem compaste / das mit an streicht / so laufen die
selbigen zungle mit dem gebele. mit dem mittag zu / sonder
der mitternacht zu / das ist zu verwundern / an disem magnete /
So ich aber die nadel halt zu dem magnete an das ort /
welches dem vorigen ort geradt entgegen ist / so zeucht der magnet
die nadel do selbst mit mer zu sich sonder treybts und stossts
von sich / und das selbig ort / das die nadel also von sich
treybt / das selbig ort das ist das mitternechtig tayl an dem magnet

FIG. 1—Reproduction of Hellmann's facsimile of first page of the Hartmann letter of March 4, 1544

round on the water, and swims till the north part of the stone came to the edge of the vessel in which was the water; and as often as I put back the bowl to the middle of the water, and turned the part which I had found towards the north, the bowl did not stand still but turned itself round again and swam northwards. But when I took out the magnet and stroked the forked end of the needle with that part of the magnet which always hasted and swam northward, the needle did not turn round northward, as His Majesty expected would happen, but turned itself southward. I cannot tell you how astonished His Majesty was of this experiment.

And fourthly, I have taken a needle of finger length, and in His Majesty's sight put it on a pointed rod, and have covered it with both hands, but without touching it. Then the needle ran on and on and turned from east through south back to the east, on and on till I took away my hands again. It's fine to see. During the peasant war I got an old parchment book,* in which also I find the force of the magnet: how one could make an instrument with a magnet, that moves on and on in the same form, time and manner as the heavens move; thus as the heaven revolves once round the Earth in 24 hours, so does this instrument with its magnets turn round in the same way in 24 hours, on which I would not much rely. And as I stood before His Majesty making these experiments, and His Majesty asked to have one of my magnet-stones, I gave him this answer: I have thrice wanted to present this stone to your Majesty, but your Majesty has replied that your Majesty wished not to rob me of this that I must use daily in my work, and now you desire it from me. Then His Majesty replied laughing: "I did not then know that you had two magnets. I have just now found it to be so." Therefore I gave His Majesty the magnet, for which His Majesty honorably recompensed me; and now I have had a letter from Prague that His Majesty wishes to know what further I have since found out. Such experiments your Grace can do for yourself, when you have got a good little magnet, if it is good all is easily done.

Georg Hartmann, Vicar of St. Sebaldus, Nuremberg.

*Hellmann says this obviously means the letter of Peter de Maricourt (see pp. 6-17 of the March 1943 number of the Journal).

EDMOND HALLEY AND GEOMAGNETISM*

By Sydney Chapman

This annual lecture, commemorating Edmond Halley, a great son of Oxford, is devoted to astronomy and terrestrial magnetism. My subject to-day is Halley's geomagnetic work considered in its historical setting, but I will preface this by a few remarks on Halley as poet—a seldom remembered aspect of his remarkable versatility.

Halley's Latin verses

Halley is known to have written three poems, all in Latin.**

The first and major poem, consisting of 48 hexameters, was written when he was 30 or 31. It is in praise of Isaac Newton, and was prefixed to the "Principia," which Halley published at his own expense and care. As Professor Plummer showed in his Halley Lecture† last year, the supreme merit of Newton's work was not immediately and universally recognized. But Halley was in no doubt, and we may imagine his joy and satisfaction in being privileged to evoke Newton's immortal work and to bring it before the world. The hexameters are written in this spirit.

In the second edition of the "Principia," edited by Roger Cotes, Bentley amended some of Halley's lines, without leave; in the third edition, edited by Pemberton in 1726, Halley restored most of the original readings.‡

As Latin is now less commonly understood than in Halley's time, I venture to give an English version of this poem made by my wife. This is naturally less concise than the original; the 48 Latin lines become 68 in the English.

The poem mentions many of Newton's main discoveries, and describes how Newton has enlarged man's powers and raised him still further above the animals. Finally it acclaims Newton himself as having done more for mankind than any of its moral and social leaders or the discoverers of the useful arts, placing him of all men next to the Deity.

*Printed with permission of the Editors of *Nature*, in which Journal the Lecture, in its final form as given at Oxford in the spring of 1943, is to be published. We are indebted to Prof. Chapman for this material in its first draft and for the opportunity of presenting so interesting an account of the human and scientific sides of Halley.—*Ed.*

**He used Latin also in his first paper in the Royal Society's Philosophical Transactions, in his Catalogue of the Southern Stars, and occasionally in later papers. Hevelius, in a letter of 5 July 1670 to the Royal Society (published in the Phil. Trans. for that year, pp. 2059-2061) opens with the sentence "Would to God, that those Excellent Books that are publish'd in English, were, for the benefit of the whole Learned World, made Latin."

†Nature, **150**, 249-257 (1942).

‡See pp. 203-206 of ref. 4; an English version, first published in 1755, is there reproduced with some comments (see pp. 207, 208).

To the Honour of
this mathematical-physical work
of the most excellent

ISAAC NEWTON

a signal glory of
our Century
and of our human
Race

Behold, to thee the Rule that guides the Pole
  To thee the balance of the Massive Whole
To thee the Skies, Jove's holy seat sublime
  Count out their numbered path through Space and Time.
By what Set Laws the All-Father has confined
  His own Creative Act thou hast divined,
Hast shewn wherein the Great Creator laid
  The Firm Foundation for the world he made.
The Inmost Secrets of the Conquered Sky
  Lie open to thy wise discerning eye;
And that same Wisdom all undaunted probes
  The Force that spins around the furthest globes.
The Sun commands all things, descending prone
  To rush towards him, seated on his throne;
The Starry Chariots suffers not to trace
  Straight Paths through the Enormous Void of Space;
Himself the Centre, drawing each, he sways
  The Ordered Circuit of their Starry Ways.
Known now the Path the Dreadful Comets weave;
  The Bearded Stars no more our minds can grieve.
Wherefore the Silver Moon with varying gait
  Speeds on, from thee we learn, though learning late;
Know how she hid, until thy wiser days
  The secret of the Curb which She obeys.
We learn from thee wherefore her nodes regress
  And why her apses ever forward press.
When Wandering Cynthia doth the sea compel
  How Great the Force thy doctrine now can tell,
Measure her Strength, when tired waves leave the shore
  And show the sailor sands he guessed before,
Or when, in turn, returning on their way
  They seek the utmost marge, beneath her sway.
Those problems which the ancient scholars vexed
  Those noisy contests which the Schools perplexed
Plainly we solve—thy lore dispels the cloud
  And by dull error now no head is bowed.
For us thy wit has trod Celestial Ways
  And shown the steps of heaven to our gaze.
Mortals, arise! shake off your earthly cares
  This Man our Heavenly Origin declares

For fellow minds of such a Master Mind
Are far removed from all the Brutish Kind.
Less did they raise to better things our life,
Our human life, who taught that bloody strife,
That theft, adultery and fraud's wicked guile
Are cursed, and wrote their Lore with graver's stile.
Less he, who to fierce tribes that wandered rude
Taught city life and their wild fears subdued,
Bade them live safe, held in a wall's strong arm.
Less he, who taught the hungry folk to farm.
Less he, who pressed with new devised craft
From the sweet grape her care-dispelling draught.
Less he who, plucking the Nile-watered reed,
Made from it paper, wrote thereon his screed
To painted picture linking spoken sound.
All these for human woes great solace found,
But we of Superhuman Joys are free.
We know the Law that guides the poles, we see
The hidden secret of dark earth unsealed
And Matter's Changeless Ordering revealed.
Such knowledge, hidden from an earlier age,
Is now, through thee, to us an open page.
O Muses, sing with me this Great Man's praise
Ye who are fed with nectar, tune your lays.
Newton, to Truth's locked Shrine has found the Key
Newton whose heart is pure, in whom we see
The Godhead's Favoured Friend to whom is given
The Nearest Place a man may win to Heaven.

Halley may have written another poem*, now lost, in the year 1687 when the "Principia" was published. His two other known poems appeared 13 years later, on his famous magnetic charts; this too must have been for him a time of great joy in achievement. One poem was in praise of Queen Anne, and is now of little interest; the other, of much greater artistic merit, lauded the unknown inventor of the compass.**

The magnet and the compass

The science of geomagnetism has a long history. In our time its earlier phases have been studied especially by Crichton Mitchell [see 1 of "References" at end of paper], and in the preceding generation by Hellmann [2] and Sylvanus Thompson [3].

The attraction of iron by the magnet or loadstone was known to antiquity, and is mentioned by Plato and many later writers [3]. The directive property of the magnet was discovered much later; Crichton Mitchell [1*a*], after reviewing the available evidence, concludes that it was certainly known to the Chinese in the eleventh century, and in Europe in the twelfth. A Chinaman Shon-Kua (A. D. 1030-1093) wrote that "fortune-tellers rub the point of a needle with the stone of a magnet

*See pp. 203 and 87 of ref. 4.

**English translations of these two poems are given in Occasional Notes of Royal Astronomical Society, No. 9.

in order to make it point south." Before 1200 Alexander Neckam, a monk of St. Albans, described the mariner's compass, in which a magnetic needle swings on a pivot, as being in common use.

The compass points south, said the Chinaman, north said the Europeans; both were right. Though the choice is arbitrary, it affected men's ideas as to the cause. In Europe the Pole Star was often supposed to attract the north end of the needle.

Nowadays a boy's first lesson on magnetism describes the dipolarity of magnets, the north and south poles (named by means of the directive property), the repulsion of like poles and the attraction of unlike. Petrus Peregrinus in 1269 gave the first known systematic record of these facts, in a letter* from Italy to a home friend in Picardy. Manuscript copies spread the knowledge; the letter was not printed till 1558. Though it includes a description of an ingenious magnetic perpetual motion machine, the letter is generally clear and modern in spirit; Petrus wrote from actual experiment, mostly using loadstones cut to the spherical form.

The magnetic declination

The recognition of the magnetic declination‡ as a general fact of Nature came only gradually. The declination of the compass from the true north cannot be measured without first determining the meridian at the place of observation, and this requires skill. At first the declination was ascribed to faults in the magnetic needle or in the measurement. Even in 1701 two needles used by Halley on his magnetic voyages gave readings of the declination at London that differed by $20'$; in the fifteenth and sixteenth centuries the errors in magnetic azimuths might be a few degrees. Nowadays at magnetic observatories the declination is read** to $0'.1$, though this requires great skill and care.

Early sun-dials and maps

Our earliest dated records of the magnetic declination are not written ones. In the fifteenth century portable sun-dials† were used by travelers and others to tell the time; they included a magnetic compass by which to set the noon line. Some dial-maker who had determined his true meridian must have noticed that the magnetic setting was erroneous, so he put a mark on his dials to which the needle should point. The angle between this mark and the north point of the dial showed the declination, as reckoned by the maker. Dated dials made at Nuremberg at about 1450 show that the declination there was then about 7° east.

A little later, before 1500, road maps made by Etzlaub of Nuremberg† bear instructions for their use in association with the traveler's compass, and show clearly that the declination was known. A compass-card printed on one such map has an arrow pointing 11-1/4° east (one-eighth of a quadrant, the smallest unit then commonly used in stating wind-directions).

*See p. 6 of ref. 1*b*, No. 10 of ref. 2*c*, p. 11 of ref. 3, and Terr. Mag., **48**, 6-17, 1943.

‡Or magnetic *variation*, as it is called by seamen and many old writers on geomagnetism.

**See p. 31 of last entry in ref. 1.

†See ref. 2*a* and §9 of ref. 1*b*.

Columbus and the declination

Crichton Mitchell [§§10-25 of 1*b*] has carefully examined the statements often made that Columbus, on his West Indian voyage in 1492, discovered the declination or the fact that it is not everywhere the same [2*a*]. He concludes adversely on both points, stating that Columbus misinterpreted the differences observed between his compass-readings; he also rejects similar claims made on behalf of the Cabots.

Measuring the declination

The first printed instructions for measuring the declination were given in the earliest printed treatise on navigation, by a Portuguese writer Falero,* in 1535. They were mainly astronomical, to determine the true meridian. Magellan seems to have taken a manuscript copy of this book with him in 1519 on his voyage round the world. The first notable series of 43 observations of the declination were made by the great Spanish navigator de Castro, in a voyage to the East Indies and the Red Sea, 1538-1541. The custom spread to later navigators, and knowledge of the declination in various seas slowly grew.

But this knowledge was very imperfectly diffused, and many landsmen and seamen in other countries remained ignorant of the methods used and the observations made by the navigators of Spain and Portugal. Most writers on magnetism and dials up to 1600 fail to refer even to the existence of the declination.**

Hartmann's letter: A. D. 1544

The earliest known written record of the declination gives it for Rome, 6° east, in 1510. It occurs in a letter† sent by Georg Hartmann in 1544 to Duke Albrecht of Prussia, and was made while Hartmann, a mathematician, instrument-maker, and later vicar of a Nuremberg church, was studying in Rome. In Nuremberg, when he wrote, he found the declination to be 9° or 10° east.

This letter contains also the first mention of the magnetic dip. It describes how a needle perfectly balanced before it was magnetized dipped about 9° after being stroked by the loadstone. Hartmann contented himself with this private mention of his observation, which he regarded as one more wonder and mystery of the magnet; the dip must really have been much more than 9°. The letter remained unknown in the Königsberg archives till 1831.

Robert Norman

In 1581 Robert Norman, a London seaman and instrument-maker, published "The Newe Attractive," a small book said by Hellmann to be the first printed work purely on geomagnetism. It announced the discovery,‡ probably in 1576, of the magnetic dip, which Norman gives as 71° 50′.

*Refs. 2*a* and No. **10** of 2*b*; also Terr. Mag., **48**, 80-84, 1943.

Ref. 2*b*; see Terr. Mag., **4, 80, 86 (1899).

†Refs. 2*a*, 2*b* (No. **10**), 1*c*, and Terr. Mag., **48**, 127-130, 1943.

‡See No. **10** of ref. 2*b*, Note 5 of ref. 1*c*, and p. **11** of ref. 3.

The book also described new experiments of great interest. Norman showed that when care is taken a floating compass is not drawn bodily northward, but only turns on its center; hence, said he, earlier writers erred in discussing where lies the *point attractive* of the compass; the compass is not attracted to any point, but there is a point which it respects and turns to; so he discarded the old term *point attractive* for his new term *point respective.*

In making this important distinction he did not discriminate between the whole compass and its northern end, to which he, like earlier non-Chinese writers, gave a preference. As the northern end dipped, he located the point respective in the Earth.

Important ideas were struggling to birth in the mind of this practical seaman and mechanic, more discerning than Hartmann. He was right in concluding that the Earth, not the heavens, directed the magnetic needle; but his argument was faulty in that it depended on an unconscious preference for the north end of the needle. The idea of a couple acting on the needle still lay far in the future, beyond even Halley a century later.

William Gilbert

William Gilbert, Queen Elizabeth's physician, laid a firmer foundation for Norman's conclusion. In the great treatise "De Magnete" (1600), Gilbert announced that the Earth itself is a great magnet. This book, written in Latin, describes a great variety of his own experiments, and clearly distinguishes between magnetic and electric attractions. Gilbert chiefly used spherical loadstones, like Petrus Peregrinus 3-1/2 centuries before; he carefully explored how tiny magnetic needles, free to turn on their centers, set themselves when placed at different points near such a stone or terrella. He found that at the "equator" of the stone, midway between its poles, the needle would lie along the surface, whereas nearer the poles one or other end would dip; by means of the needles he marked out on his terrella, with chalk, the magnetic meridians or lines of horizontal magnetic force, converging to the two poles.

He pointed to the analogy between the poleward direction of these little needles on the sphere, and the northward direction of compass-needles on the Earth. He fortified the analogy by Norman's observation of the magnetic dip,* roughly equal to the dip of his little needle on the sphere, when placed in a similar "latitude." As the magnetism of the terrella obviously controlled the direction of his needles, he inferred, as Norman had done, but now with more reason, that the Earth controls the direction of the compass or dip-needle. Going beyond Norman, he realized that the Earth itself is a great magnet.

Thus he showed that the directive property of the magnet, which hitherto had been regarded as a phenomenon distinct from its attractive or repulsive action, was really only a manifestation of the same power, in relation to the Earth magnet, whose bigness had till then hindered this recognition.

Gilbert commended Norman's rejection of the old idea of a *point attractive*, but himself rejected Norman's *point respective*, because the little needles, placed at different points on the terrella, met in no common

*Gilbert called the declination the variation, and the dip the declination.

point. The whole Earth, he said, exerts the directive power, not merely the center or any other single point.

The distribution of the declination

Falero, in the treatise already mentioned, stated without any warrant from observation that the magnetic declination was distributed regularly over the Earth. At that time the declination was zero at one of the Azores. Falero said that, going eastward from this meridian, the declination would be east, and would regularly increase over the first 90° of longitude; thence it would regularly decrease to zero in the next 90° of longitude; in the 180° of west longitude the declination would be westerly and would vary in the same way.

Gilbert knew that its distribution was less regular than this. He quoted (Bk. IV, Ch. 1) the declination at London and elsewhere, and concluded that the Earth's directive power was defective over the oceans (water being non-magnetic) and stronger where the land was elevated. He regarded these inequalities as disturbing the tendency of the needle towards the magnetic poles, which he supposed to coincide with the geographical poles. Halley afterwards disproved Gilbert's theory, showing that at sea the needle may point away from an adjacent continent.

*Gilbert and the magnetic dip**

Gilbert also erred like Falero in thinking that the Earth's magnetism is more regular than is the fact; but Gilbert's error concerned not the declination but the dip. He supposed that the dip depends only on the latitude, and would enable seamen to determine their latitude when clouds cover the sky. He gave an empirical theory for the magnitude of the dip, and Briggs of Gresham College, at Gilbert's suggestion, calculated a table of dip and latitude on this theory. Kircher, a Jesuit writer on magnetism, in 1643 gave a table** of computed and observed dips. Further discovery showed that the method was impracticable.

It is remarkable, in view of the importance of the dip in Gilbert's demonstration that the Earth is a great magnet, that he quoted not one actual observation of it, neither Norman's nor any made by himself, though he invented a simplified portable dip circle.†

The secular magnetic variation

Gilbert made the further unfounded assertion that at any one place the declination remains constant, unless changed by some great cataclysm like the fabled submergence of Atlantis.

This was disproved in 1634 by Gellibrand,‡ Gresham professor, who found that the declination at London was then only 4°.1 east, quite irreconcilable with the value 11°.3 east measured in 1580 by William Borough.§

Thus the secular magnetic variation came to light, which imposes on

*Pp. 59-60 of ref. 3.

**Athanasius Kircher, Magnes sive de arte magnetica, (2nd ed.), 1643, p. 368.

†Blundevile, Theoriques of the seven planets, London (1602), and p. 63 of ref. 3.

‡No. 9 of ref. *2b*.

§See Ch. 3 of No. 10 of ref. *2b*.

us the duty, both for science and practice, continually to repeat the magnetic survey of the globe. The Earth's magnetism has changed greatly in the three centuries since then, and its future, uncertain and mysterious, remains to be observed by later ages.

Halley and his magnetic needle

The story of magnetic discovery has now brought us to the time of Halley [4, 5], who was born in 1656.* While still at St. Paul's School he decided to devote his life to astronomy, which he did to such effect that his name will ever live in the annals of that science. But geomagnetism was one of his favorite secondary interests.

In 1672, while only 16 and at school, he measured the magnetic declination in London; it was 2° 30′ west, showing a further westward change of 6-1/2° since Gellibrand's observation. The laying down of the meridian for this measurement fitted in well with Halley's astronomical interests.

At Oxford he planned an expedition across the equator to observe the southernstars, and in 1676 he was enabled to go to St. Helena, through the good offices of the Royal Society, King Charles II, and the East India Company. There he spent a year (1676-77) most fruitful for astronomy. He took his magnetic needle with him, besides his astronomical equipment, and observed the declination [6, 7] at St. Helena and Ascension.

Not long after his return to England and the publication of his results, he paid an astronomical visit to Hevelius† at Danzig, where again he appears to have used his compass [6]. A little later he set out from England to make the grand tour with a friend; while in Paris and Rome he observed the declination [7]. In London he often repeated his measurement [8], for example in 1683, 1692, 1701, 1702, and 1716. In 1696, when he went to Chester as Deputy Controller of the Chester Mint, he again took his magnetic needle with him.** These observations clearly show his long-continued interest in the Earth's magnetism.

Halley's theory of the variation (declination)

In 1682 Halley married and settled down in London. The next year when his age was 27, the Royal Society published his famous theory of the distribution of the declination [6]. His aim was "to reconcile the observations by some general rule," not, as Des Cartes [9] did, by "causes altogether uncertain (as are the casual lying of iron mines and loadstones in the Earth)," which to Halley seemed to "put a stop to all further contemplation, and give discouragement to those that would otherwise undertake this enquiry."

"Tis true," he said, "that not long since one Mr. *Bond*,‡ an old teacher of navigation, put forth a small treatise wherein he pretends to calculate the variation."

Bond's theory merely supposed the magnetic axis of the Earth to

*Or possibly in 1657; see p. 34 of ref. 5.

†Hevelius also was interested in the magnetic declination, and in a letter to the Royal Society [Phil. Trans., 5, 2059-2061 (1670)] mentions his own observations of the declination at Danzig in 1628, 1642, and 1670.

**See p. 97 of ref. 4.

‡Henry Bond, The longitude found, London (1676).

be oblique to the geographical axis, so that the declination could be readily calculated anywhere. Halley saw that this theory requires the declination to have the same sign all along each geographical meridian, and showed that this did not agree with observation.†

Halley then gave a table of dated observations of the declination, made by "persons of good skill and integrity," at 48 places in many parts of the globe. He showed that these did not confirm Gilbert's theory that at sea the compass would turn to an adjacent mainland. As to Des Cartes, Halley admitted that some local irregularities of the declination, like those near Elba, might be explained by local deposits of iron ore; but he said that no reasonable amount of it could explain why the needle declines the same way all over great areas such as the whole Indian Sea. "Besides, against both Des Cartes and Gilbert, the change of the variation, which has been within this hundred years last past more that 15 gr. at London, is an entire demonstration: tho Des Cartes does not stick to say, that the transportation of iron from place to place, and the growth of new iron within the Earth, where there was none before, may be the cause thereof."

Halley himself, "after a great many close thoughts," and wishing to "introduce nothing strange in philosophy," could "come to no other conclusion than that, *The whole globe of the Earth is one great magnet, having four magnetical poles, or points of attraction, near each pole of the equator two, and that, in those parts of the world which lye near adjacent to any one of these magnetical poles, the needle is governed thereby, the nearest pole being always predominant over the more remote.*"

Halley gave the positions of the four poles, "as near as conjecture can reach," "for want of sufficient data to proceed geometrically"; and he indicated the four regions each governed mainly by one of these poles. He ended with the following admirably moderate remarks* on the declination:

"But to calculate exactly what it is, in any place assigned, is what I dare not yet pretend to; . . . ., for first there are a great many observations requisite, ... And besides, it remains undetermined in what proportion the attractive power decreases, as you remove from the poles of a magnet; without which it were a vain attempt to go about to calculate. There is yet a further difficultie, which is the change of the variation, one of the discoveries of this last century: which shows, that it will require some hundreds of years to establish a compleat doctrine of the magnetical system. . . . . it should seem, that all the magnetical poles had a motion westward: but if it be so, tis evident that it is not a rotation about the axis of the Earth. . . . . But whether these magnetical poles move altogether with one motion, or with several, ... are secrets as yet utterly unknown to mankind; and are reserved for the industry of future ages."

Halley's experiments on the law of magnetic attraction

In 1687 Halley made experiments‡ to determine "in what proportion the attractive power decreases, as you remove from the pole of a mag-

†See §9 of ref. 6.

*Ref. 6, here abridged.

‡See pp. 135-137 of ref. 4; these experiments are discussed in detail by A. C. Williams, Edmond Halley and the problems of terrestrial magnetism, London University Dissertation (1937).

net"; this was one of the needs that hindered the completion of his theory. But his work was inconclusive; the discovery of the inverse-square law of force between point magnetic poles did not come till a century later. In Halley's time several necessary theoretical conceptions were wanting —the point pole, the point dipole, the magnetic moment, the couple. Newton might have developed these had he given his close attention to magnetism; but Halley, who did so much in connection with Newton's "Principia,"† seems never to have inspired Newton with his own strong interest in magnetism.

Halley's theory of the secular magnetic variation

In 1692 Halley, aged 36, extended his theory to explain the secular magnetic variation [7]. He said that his theory of the declination had been well received at home and abroad, but he found two difficulties not easy to surmount. One was that no magnet he had ever seen or heard of had more than two poles, "whereas the Earth had visibly four, and perhaps more." The second was that "these poles were not, at least all of them, fixt in the Earth, but shifted from place to place"; "whereas it is not known that the poles of a loadstone ever shifted their places in the stone, nor (considering the compact hardness of that substance) can it easily be supposed.

"These difficulties had wholly made me despond, and I had long since given over an enquiry I had so little hopes of; when in accidental discourse, and least expecting it, I stumbled on the following hypothesis:

"Now considering the structure of our terraqueous globe, it cannot be well supposed that a very great part thereof can move within it, without notably changing its centre of gravity and the equilibre of its parts, which would produce very wonderful effects in changing the axis of diurnal rotation, and occasion strange alteration in the sea's surface, by inundations and recesses thereof, such as history never yet mentioned . . . . So that the only way to render this motion intelligible and possible, is, to suppose it to turn about the centre of the globe, having its centre of gravity fixt and immoveable in the same common centre of the Earth: and there is yet required that this moving internal substance be loose and detached from the external parts of the Earth, whereon we live; for otherwise were it affix'd thereto, the whole must necessarily move together.

"So than the external parts of the globe may well be reckoned as the shell, and the internal as a nucleus or inner globe included within ours, with a fluid medium between. Which having the same common centre and axis of diurnal rotation, may turn about with our Earth each 24 hours; only this outer sphere having its turbinating motion some small matter either swifter or slower than the internal ball."

Both the exterior shell and the nucleus were supposed to have their poles distant, by different amounts, from their poles of rotation. The exterior shell, with its magnetic poles fixed, might also have an unequal or irregular distribution of its magnetic matter, explaining the local irregu-

†Newton's Principia contains only five brief references to magnetism: In Axioms, Corollary 6; Book 2, Section 5, Theorem 18; Book 3, Theorem 6, Corollary 5; Theorem 7, Corollary 1; Problem 18, Corollary 10. The third of these references includes the sentence: "The power of magnetism . . . . in receding from the magnet decreases not as the square but almost as the cube of the distance, as nearly as I could judge from some crude observations." Newton in 1712 (see ref. 8*b*) made the same remark, when proposing, as President of the Royal Society, that Halley and Hawksbee should make new experiments on the subject.

larities in the distribution of the declination. The relative motion of the magnetic nucleus, or, should future observations require it, of the nucleus and additional inner shells, may explain the secular variation, though "it will be very hard to bring this hypothesis to a calculus."

Halley conjectured that the whole period of the secular variation is "700 years, or thereabouts; so that the nice determination of this and of several other particulars in the magnetick system is reserved for remote posterity; all that we can hope to do is to leave behind us observations that may be confided in, and to propose hypotheses which after ages may examine, amend or refute. Only here I must take leave to recommend to all masters of ships and all others, lovers of natural truths, that they use their utmost diligence to make, or procure to be made, observations of these variations in all parts of the world, ..., and that they please to communicate them to the Royal Society, ..."

Halley then answers various objections which he foresaw: One was that there is no instance in Nature of the like thing, and that if there were, the nuclei and shells would not preserve the same center. To this he answers that the ring of Saturn is a notable instance somewhat of this kind. Another objection was that water would leak through the outer shell.

"To those that shall enquire of what use these included globes can be, it must be allowed, that they can be of very little service to the inhabitants of this outward globe; nor can the Sun be serviceable to them, either with his light or heat. But since it is now taken for granted that the Earth is one of the planets, and they all are with reason supposed habitable, though we are not able to define by what sort of animals; and since we see all the parts of the creation abound with animate beings, ..., all whose ways of living would be to us incredible did not daily experience teach us. Why then should we think it strange that the prodigious mass of matter, whereof this globe does consist, should be capable of some other improvement than barely to serve to support its surface? Why may we not rather suppose that the exceeding small quantity of solid matter in respect of the fluid ether, is so disposed by the Almighty Wisdom as to yield as great a surface for the use of living creatures as can consist with the conveniency and security of the whole. We ourselves, in cities where we are pressed for room, commonly build many stories one over the other, and thereby accommodate a much greater multitude of inhabitants."

Lastly, he explains a diagram showing a nucleus and three shells, the nucleus being about 2,000 miles in diameter, and the thickness of each shell, and of each hollow between, about 500 miles, so that the four upper surfaces are "nearly proportionable to the magnitudes of the planets" Mercury, Mars, Venus, and, of course, the Earth.

"Thus I have shewed a possibility of a much more ample creation, than has hitherto been imagined; and if this seem strange to those that are unacquainted with the magnetical system, it is hoped that all such will endeavour first to inform themselves of the matter of fact, and then try if they can find out a more simple hypothesis, at least a less absurd, even in there own opinions. And whereas I have adventured to make these subterraneous orbs capable of being inhabited, 'twas done designedly for the sake of those who will be apt to ask *cui bono*, and with whom arguments drawn from *final causes* prevail much."

Comments on Halley's magnetic theories

How are we to regard this remarkable theory? To us, and probably to some of his contemporary critics, it has some flavor of Kepler in his wilder moments. Halley himself said: "If I shall seem to advance anything extravagant or romantick, the reader is desired to suspend his censure, till he have considered the force and number of the many arguments which concurr to make good so new and so bold a supposition." A sign that Halley always remained satisfied with these arguments is that a portrait painted in 1736, when he was 80, shows him holding his 1692 diagram of the Earth's nucleus and its shells.

The force and ingenuity of his arguments cannot be gainsaid, and they must be judged by the standards of knowledge and ignorance at the time they were written. But our knowledge of geophysics, especially of seismology, now precludes Halley's hypothesis.

What is more pertinent, however, is that Halley might have found for himself, by experiments like those of Petrus Peregrinus and Gilbert, using loadstones in the form of a sphere and spherical shells, that his hypothesis would not work. The theory of uniformly magnetized spherical shells still lay far in the future, but this experiment was quite open to Halley, and would have shown him that despite the differing directions of the magnetic axes of the nucleus and shells, the field at the outer surface would have only two poles.

We know now that despite the irregular distribution of the Earth's field, there are only two magnetic poles, to which converge all the magnetic meridians (drawn as Gilbert did on his terrella). Halley's own later knowledge would have enabled him to draw many of these meridians, and to discover this fact; the first actual chart of the Earth's magnetic meridians was made in 1817, by another Englishman, Thomas Yeates.*

The irregularities of the Earth's field imply a more detailed irregularity in the inner causes than Halley's hypothesis suggested, and the secular variations are regional in character, not so regular and worldwide as he supposed.

The causes of the main field, of its irregularities, and of its secular variation, are still unknown. It seems likely that the secular variation is connected with convective motions inside the Earth, whose substance becomes first plastic, and then liquid, with increasing depth.

Halley's magnetic voyages and charts

Halley's magnetic theories extended and maintained interest in magnetic observation. Already in 1692 Halley was associated** with a plea by Benjamin Middleton, a Fellow of the Royal Society, for the Society's assistance "to procure for him a small vessell of about 60 tuns to be fitted out by the Government, but to be victualled and manned at his own proper charges. And this in order to compass the globe, to make observations on the magneticall needle, &c. The President in the name of the Society promised to use his endeavours towards the obtaining such a vessell."

This plan came to nothing, but in 1698 Halley was granted a vessel,

*Copies of his chart are in the British Museum Library [Catalogue No. 974 (2)] and the Admiralty Library.

**See p. 186 (Hooke's notes for 11 January 1692/3 and 12 April 1693) and also footnote 2 of ref. 4.

the pink *Paramour*, by King William III, "to improve the knowledge of the longitude and the variations of the compasse." Moreover this landsman of 42 was put in command of the vessel, with a Captain's commission in the Royal Navy—a remarkable event which his deeds well justified.

He sailed in November 1698, but trouble with an insubordinate Lieutenant caused him to return from the West Indies the following summer, without having crossed the equator. He set off again in September 1699, and after a magnetic survey of the North and South Atlantic down to a high southern latitude he returned in August 1700.† In 1701 he published his first chart of the declination over the Atlantic Ocean. In 1702, having collected further observations by mariners in other oceans, he produced a World Magnetic Chart.*

These famous charts are Halley's greatest contribution to geomagnetism; they give the declination in a way** very convenient to the navigators for whom they were made, and by whom they were widely used for 40 years. In time, as Halley foretold, their practical value came to an end, owing to the secular magnetic variation, and new charts replaced them. But the value of Halley's observations as a record of the declination at the epoch 1700 remains imperishable.

One may lament, however, an astonishing gap in Halley's geomagnetic work, his apparent total neglect of the magnetic dip—a fact most surprising in view of his great geometrical knowledge and insight, and of the importance given by Gilbert to the dip in his demonstration that the Earth is a great magnet. The dip-circle is a more difficult and less accurate instrument than the compass, but its reference-direction, the horizontal, is much more easily obtained than the meridian needed in observing the declination. Had Halley observed the dip as well as the declination our debt to him would have been doubled; but where so much is owed, gratitude and admiration must far outweigh these vain regrets.

Halley's later geomagnetic work

At least as late as 1721 Halley's published papers manifest his continued interest in geomagnetism. He became the channel by which many observers sent their magnetic measurements to the Royal Society. He likewise presented and discussed many series of observations of two great auroras visible in London, in March 1716 and November 1719. He acutely recognized some of the relations between the auroras and the geomagnetic field, both as regards the location of auroras in high magnetic latitudes, and the parallelism of their rays with the magnetic dip-needle.

Halley seems to have contemplated further magnetic voyages, because in 1705 Leibniz,‡ replying to an astronomical enquiry from Halley, who had then become Savilian professor of geometry, genially expressed the hope that younger men would be found to take over the further little

†See pp. 8, 9, 21, 22, 103-115, 243-247 of ref. 4 for much interesting information on Halley's magnetic voyages.

*See these Occasional Notes of Royal Astronomical Society.

**The method had previously been used by Christopher Burro, who made an isogonic chart mentioned by Kirchner (*loc. cit.* p. 443).

‡See p. 201 of ref. 4 and p. 60 of ref. 5.

excursions of a few thousand leagues which Halley had been considering, to complete his solution of the great magnetic enigma.

But for two centuries Halley had no comparable successor in this field, and the magnetic survey of the globe was not renewed with his abounding zeal until in 1905 the young American, Louis Bauer, with the backing of a prince of industry, the one-time poor Scots lad Andrew Carnegie, resumed the Sisyphean task.

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PERIODIC CHANGES IN $\triangle D$ AT OSLO, 1843-1930

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Introduction—Christopher Hansteen began measurements in 1842 of magnetic variation at the Oslo Observatory (latitude = 59° 54′.7 north, longitude = 10° 43′.4 east). Daily readings of declination (D), horizontal intensity (H), and inclination (I) were made, almost without interruption during 1842-1930. Observations were made twice daily—at 09^h and 14^h local mean time (LMT).

Table 1—*Mean values of* $\triangle D = (D_{14} - D_9)$, *Oslo, 1843-1930, grouped according to seasons*

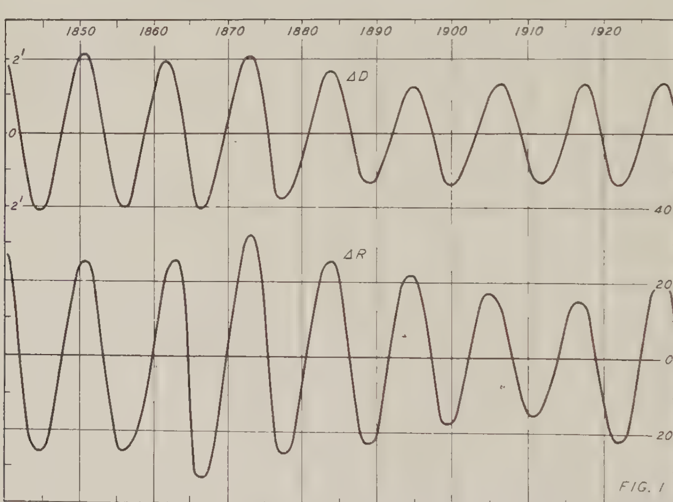
Year	0	1	2	3	4	5	6	7	8	9
	′	′	′	′	′	′	′	′	′	′
					Winter					
1840	...	...	...	2.7	2.0	2.0	2.5	2.8	5.6	6.6
1850	5.7	3.3	5.2	5.2	3.8	3.2	3.0	2.0	3.5	5.3
1860	6.3	4.4	3.9	4.1	3.2	2.5	3.8	3.3	2.9	4.1
1870	4.2	6.5	8.4	4.2	4.7	2.1	2.4	2.3	1.9	1.7
1880	2.8	3.0	4.8	3.3	4.8	3.4	4.5	2.4	2.3	2.4
1890	2.6	3.2	4.0	4.6	6.2	3.3	3.2	3.9	2.7	1.8
1900	1.7	2.0	1.7	2.7	1.4	4.0	4.8	2.6	1.9	1.8
1910	3.0	2.3	0.7	3.1	2.1	1.8	2.8	3.8	4.8	2.0
1920	4.9	1.3	1.0	2.3	1.9	4.2	4.9	4.1	4.7	4.5
1930	3.3	...	...	...	...	...	...	...	...	...
					Spring					
1840	....	...	...	6.7	7.4	8.7	9.1	9.6	10.2	11.4
1850	11.1	9.4	8.0	7.5	8.6	7.0	6.5	7.2	9.9	11.1
1860	10.7	11.1	8.2	9.7	8.9	9.2	7.4	8.0	8.9	9.2
1870	12.9	11.5	11.0	10.5	9.3	7.9	7.0	6.7	7.1	6.9
1880	8.4	8.7	10.1	9.4	10.7	9.0	9.0	6.8	6.7	6.6
1890	6.9	8.1	9.5	12.8	11.0	9.7	9.1	8.5	7.6	7.1
1900	7.1	6.8	7.0	5.0	7.7	8.0	10.2	9.5	7.3	7.2
1910	7.2	6.8	6.9	7.4	6.7	8.9	9.9	9.9	10.5	9.6
1920	8.3	9.4	7.2	7.0	7.7	8.6	9.6	11.0	11.3	10.2
1930	6.7	...	...	...	...	...	...	....	....	....
					Summer					
1840	....	...	...	9.2	7.4	7.4	9.4	11.0	13.1	10.0
1850	10.5	9.4	8.5	10.3	8.6	6.5	7.3	8.5	8.8	11.2
1860	11.2	10.2	9.8	9.6	8.3	7.6	7.9	8.4	9.2	10.9
1870	13.0	12.7	12.9	10.0	9.5	8.3	8.7	8.3	7.7	8.7
1880	9.2	9.4	8.7	9.9	9.1	9.9	8.6	6.8	8.6	7.8
1890	7.1	9.1	10.1	12.3	9.8	10.4	8.0	8.1	8.3	7.8
1900	7.9	7.5	7.3	8.8	9.9	9.3	9.9	8.1	7.9	7.9
1910	7.5	7.2	7.1	7.5	7.4	9.3	9.4	12.3	10.8	11.6
1920	9.3	9.2	7.1	7.2	8.5	8.9	10.3	10.3	11.7	9.5
1930	7.0	...	...	. .	...	...	....	....	....	...
					Autumn					
1840	...	...	...	4.1	4.1	3.8	5.0	8.3	8.6	6.4
1850	6.5	6.0	5.5	5.5	4.5	4.6	4.3	4.7	7.7	8.6
1860	7.4	7.6	6.1	5.2	3.2	4.3	3.3	3.8	4.6	7.0
1870	9.0	8.1	7.8	6.3	5.9	3.9	4.4	3.9	3.7	4.7
1880	6.2	6.0	6.0	7.1	7.1	5.6	4.8	3.8	3.9	4.2
1890	4.1	5.9	6.5	7.9	6.2	5.9	4.8	5.5	4.6	4.7
1900	3.7	3.8	3.2	4.6	6.0	7.4	4.7	6.2	5.1	4.8
1910	4.0	3.1	3.6	3.7	3.9	6.1	5.1	7.5	6.7	6.6
1920	5.2	5.0	4.1	3.6	5.0	6.8	5.4	6.2	6.5	6.3
1930	5.0	...	...	...	...	...	...	...	...	...

The results for H have been published [see 1 and 2 of "References" at end of paper]—the first gives complete tables of daily values for H at 09^{h} and 14^{h} and for $\triangle H=(H_{14}-H_{9})$, while the second summarizes and discusses the results.

Similar compilations and discussions for D are in preparation; the table for $\triangle D=(H_{14}-II_{9})$ is now completed. The annual mean values of $\triangle D$, as given in Table 1, are here discussed as regards possible periodic phenomena.

The 11-year period—Harmonic analysis was used to test for a 11-year period. As there might exist a seasonal distribution in the amplitude of $\triangle D$, the four seasons were treated separately. The method of harmonic analysis may be applied directly or indirectly according to the nature of the variation. In this case the graphs for the data are of an approximately periodic nature and the direct method was used therefore [see 3].

Each 11-year epoch was examined separately in order to get the presupposed length of the periodic movement tested. The results for phase-angles, amplitudes, and years of maximum for each epoch, and the number of years between each epoch are given in Table 2. Table 3 summarizes the corresponding data for sunspots. The 11-year period in $\triangle D$ and in sunspots are graphed in Figure 1 for 1843-1930. Figure 2 shows



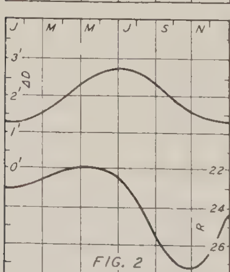


FIG. 1—COMPARISON 11-YEAR PERIOD IN ΔD AT OSLO WITH CORRESPONDING VARIATION IN SUNSPOTS, 1843-1900

FIG. 2—MEAN ANNUAL RANGES IN ΔD AND SUNSPOTS

the graph for the mean annual data for the range in $\triangle D$ and the corresponding curve for sunspots. Table 4 summarizes the seasonal change in the harmonic constants for the 11-year variation in $\triangle D$ and for sunspots.

TABLE 2—*Phase-angles and amplitudes, 11-year-period epochs of maximum, and periods in $\triangle D$, Oslo, 1843-1930*

No.	Interval	A	a	Epoch maximum	Period
		° ′	′		*years*
1	1843–1853	241 35	2.20	1850.4	
					11.0
2	1854–1864	241 30	1.97	1861.4	
					11.2
3	1865–1875	239 35	2.09	1872.6	
					10.5
4	1876–1886	234 36	1.73	1883.1	
					11.5
5	1887–1897	240 24	1.35	1894.6	
					11.0
6	1898–1908	251 46	1.44	1905.6	
					11.2
7	1909–1919	254 36	1.40	1916.8	
					10.4
8	1920–1930	233 47	1.47	1927.2	
Means..........		242 29	1.71	......	10.8

TABLE 3—*Phase-angles and amplitudes, 11-year-period epochs of maximum and periods in sunspots, 1843-1930*

No.	Interval	A	a	Epoch maximum	Period
		° ′	′		*years*
1	1843–1853	250 25	26.1	1850.7	
					11.0
2	1854–1864	255 21	26.4	1862.6	
					10.3
3	1865–1875	257 26	33.3	1872.9	
					10.9
4	1876–1886	252 38	26.6	1883.8	
					10.8
5	1887–1897	248 32	23.8	1894.6	
					10.4
6	1898–1908	231 37	18.2	1905.0	
					11.0
7	1909–1919	230 01	15.7	1916.0	
					11.4
8	1920–1930	241 42	22.3	1927.4	
Means..........		246 00	24.0	......	11.0

The amplitude of the 11-year variation (see Fig. 1) steadily diminished from 1840 to 1930, more or less in correspondence with the amplitudes in the 11-year variation of sunspots, except for a small rise between 1840 and 1930.

The 11-year variation in sunspots is of a complex nature, as also for most of the geophysical elements, where the 11- and 8-year periodicities are more prominent. The data for $\triangle D$ give no evidence of an 8-year variation, and it is concluded that this period does not exist in $\triangle D$.

The 8-month period—Another most interesting periodicity has been traced, however, for $\triangle D$, namely, an 8-month variation. Wolf, studying the periodicity of the sunspots, found traces of a period of about a month and suggested that this variation might have something to do with the conjunction every 236 days of Jupiter and Venus. Both Krogness and Helland-Hansen and Nansen have examined their material to test the existence of this interesting undulation; they seem to have succeeded in showing (1) that Wolf's assumption was well founded and (2) evidence of a similar variation in terrestrial elements—such as air-temperature, sea-temperature, and other geophysical elements.

Figure 3, based on sunspot-data, 1905-17, shows that the 8-month period is fairly well developed. Figure 4 shows $\triangle D$ at Oslo for the interval 1840-1930; the directly observed data are shown by light lines

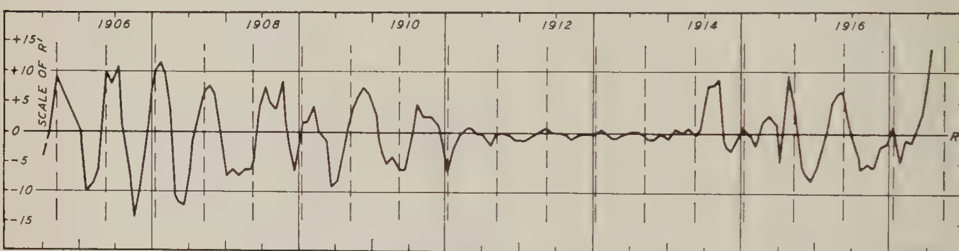


FIG. 3—EIGHT-MONTH PERIOD IN SUNSPOTS, 1905-17

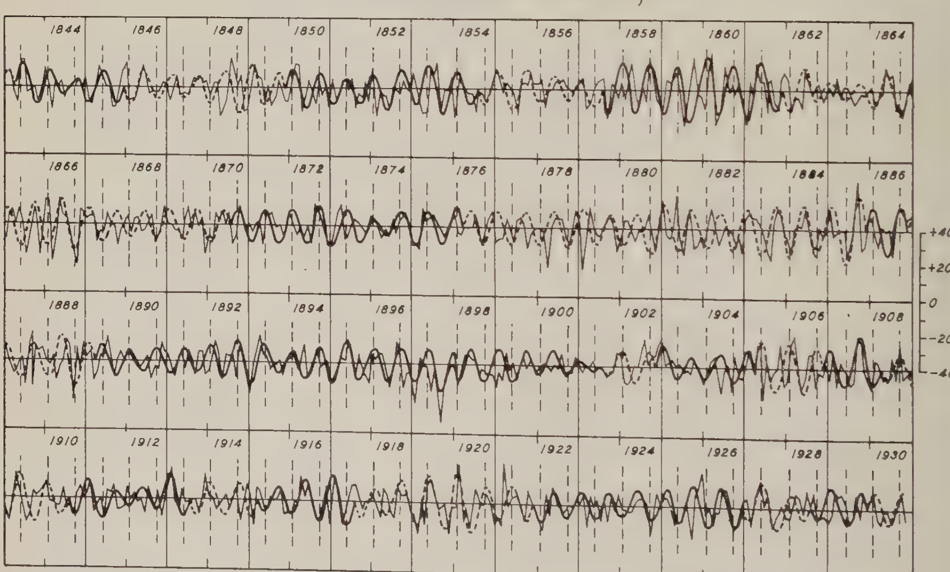


FIG. 4—EIGHT-MONTH VARIATION IN ΔD, OSLO, 1840-1930

LEGEND:
—— = OBSERVED VALUES; —— AND - - - = COMPUTED VALUES ALTERNATELY SO INDICATED TO SHOW PHASE-CHANGES

joining plotted monthly values, while the theoretical curve is drawn alternately as a heavy and as a dashed line in order to emphasize phase-changes.

TABLE 4—*Seasonal change in harmonic constants of 11-year variation in $\triangle D$ for Oslo and in sunspots*

Season	The 11-year period					
	A	*a*	Period	*A*	*a*	Period
	° ′	′	*years*	° ′	′	*years*
Winter	239 21	1.23	11.0	243 12	23.2	10.9
Spring	251 43	2.04	11.0	246 21	22.2	11.0
Summer	238 25	2.63	10.8	249 48	23.3	10.9
Autumn	237 13	1.66	11.0	244 55	27.5	11.0
Year	241 40	1.89	11.0	246 00	24.0	11.0

TABLE 5—*Amplitudes of 8-month variation in $\triangle D$, Oslo, 1840-1930*

No.	1	2	3	4	5	6	7	8	M
	′	′	′	′	′	′	′	′	′
1	2.5	2.0	2.2	2.0	2.0	1.6	3.0	3.5	2.4
2	1.9	2.0	2.6	1.8	2.2	1.8	1.8	2.0	2.0
3	1.5	2.4	3.0	1.6	3.2	1.6	2.2	1.2	2.1
4	2.5	1.6	2.0	1.6	2.4	1.2	1.8	2.2	1.9
5	2.1	1.4	1.6	2.4	2.5	1.2	1.2	1.4	1.8
6	0.8	3.0	1.8	2.2	1.0	1.6	1.8	1.6	1.8
7	1.2	3.0	2.0	2.4	1.8	2.0	2.0	1.6	2.3
8	2.8	2.6	2.0	3.4	1.4	2.0	2.0	2.0	2.3
9	2.8	4.0	2.0	2.4	2.4	2.0	1.8	2.2	2.4
10	1.5	3.0	1.8	2.2	3.0	1.6	1.6	3.0	2.2
11	2.8	3.2	2.0	2.4	2.0	2.0	2.2	2.4	2.4
12	1.7	2.4	2.4	2.8	1.8	3.0	3.0	2.4	2.4
13	1.7	1.0	2.0	2.8	2.2	3.0	2.8	1.4	2.1
14	2.6	1.0	1.0	3.0	2.2	2.0	1.8	1.8	1.9
15	1.7	2.0	2.0	4.0	2.0	3.0	1.8	2.4	2.4
16	2.5	2.4	2.0	2.4	3.4	1.8	2.8	2.0	2.4
M	2.0	2.1	2.0	2.4	2.2	2.0	2.1	2.1	2.2

Approximate measurements indicate amplitudes as in Table 5. The 16 waves measured in each 11-year epoch are tabulated vertically from 1 to 16. Thus there are $8 \times 16 = 128$ values for the amplitudes recorded. Inspection of these mean values both in the vertical and the horizontal rows suggests an 8-year variation; this is evident from Figure 5 in which the vertical values are plotted. This result is most interesting, because no trace of any 8-year variation was indicated on examination of the direct data for $\triangle D$.

The secular variation in $\triangle D$ and in D at 09^h—The secular variation of $\triangle D$ shows a gradual fall of about 1′.8 between 1840 and 1930 and suggests a somewhat irregular undulation with a period of between 28 and

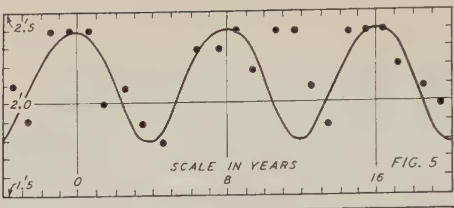
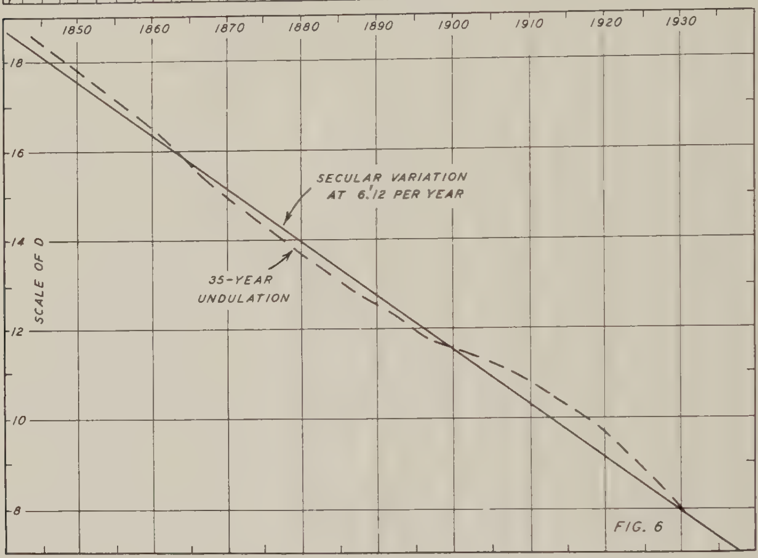


FIG. 5—MEAN VARIATION IN AMPLITUDE OF ΔD, OSLO, 1840-1930

FIG. 6—SECULAR VARIATION OF DECLINATION (D), OSLO, 1840-1930



30 years above and below the line which would represent linear change in secular variation.

The curve for secular variation of D is of considerably greater interest. The data for D, based on the means of values observed at 09^h and 14^h, are plotted in Figure 6, which shows that D progresses steadily eastward 6′.12 a year. This linear change is shown by the straight line; the plotting of the direct data for D shows an undulation above and below this line and suggests a period of about 35 years. It is suggested that this 35-year period in D corresponds to the well-known Brückner variation of air-temperature and precipitation [see 4 for a possible explanation].

References

[1] K. F. Wasserfall, The horizontal component of magnetic intensity at Oslo Observatory, 1843-1930, Geofys. Pub., **13**, No. 2, Oslo, (1941).

[2] K. F. Wasserfall, Magnetic horizontal intensity at Oslo, 1843-1930, Terr. Mag., **46**, 173-218 (1942).

[3] K. F. Wasserfall, How the Brückner cyklus may be explained, Zs. Gletcherkunde, **20**, 440-444 (1932).

[4] K. F. Wasserfall, Comparison of long periodic variations in magnetic elements and air-temperatures, Terr. Mag., **46**, 417-430 (1941).

Magnetisk Byrå,
Bergen, Norway, March 4, 1943

THREE-HOUR-RANGE INDEX, K, AT DOMBÅS OBSERVATORY DURING 1939 TO 1942

By K. F. Wasserfall

Introduction—The following resolution was adopted [see 1 and 5 of "References" at end of paper] by the Washington Meeting of the International Association of Terrestrial Magnetism and Electricity in September 1939: "That cooperation of magnetic observatories be sought for a three-year period (1940-42) in an international trial-scheme for provision of three-hour-range index K, to characterize the variation in degree of irregular magnetic activity throughout each day, especially in order to meet the request made by the International Union of Scientific Radio-telegraphy and other bodies for information concerning the magnetic activity more detailed than the present daily magnetic character-figure, and that this trial-scheme should replace the scheme for a numerical character-figure."

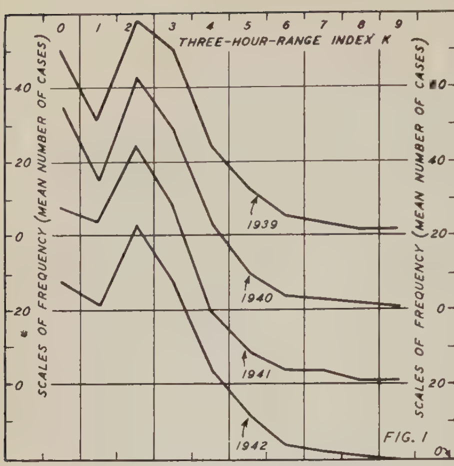
The so-called "Potsdamer erdmagnetische Kenziffer," which was introduced for Potsdam at the beginning of 1938 [2], served as a model for the index K. Bartels, Heck, and Johnston [3] have given a definition of K; here it will suffice to say that this definition agrees more or less with that for the quantity "storminess" (S) as defined by Krogness and Wasserfall [4]. For S, as well as for K, the range is the difference between the curve actually registered and an arbitrary curve showing quiet conditions. The curve for quiet conditions includes, for "absolute storminess" (AS), the mean daily and day-to-day quiet variations, Q and C, respectively, and for K the combined effect of S_q, L, and D_{ma}, where S_q is the solar daily variation, L the lunar daily variation, and D_{ma} the after-effect of the disturbing-field (the effect of the decay of the ring-current), and the non-cyclic variation on quiet as well as that on the disturbed days [3].

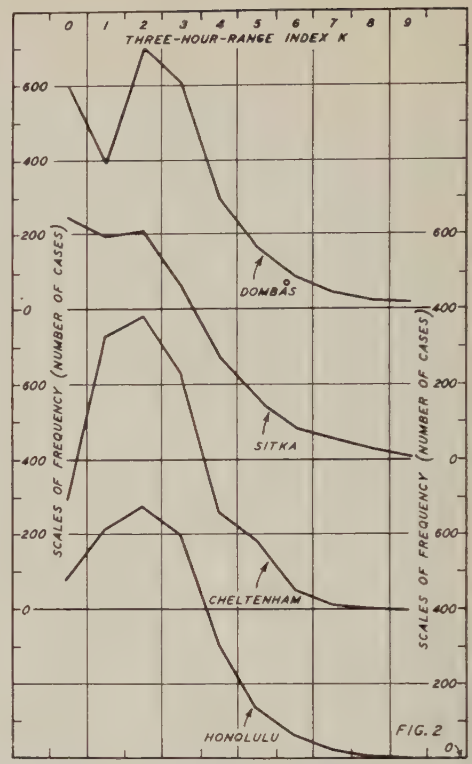
For the three-hour range, R, only the largest of the three values of R for each interval—that is, R for the most disturbed element—is taken into account in determining K [5]. Which element will be the most disturbed will depend principally on the geographical position of the station concerned. D and H are more or less equally represented at Dombås as long as the magnetic conditions are comparatively quiet but, with the beginning of an actual disturbance, the range in H is almost always the larger; in a very few cases, however, the range in Z is in excess of ranges in D and H. The ranges adopted for various values of K at Potsdam (Niemegk) are

$$\begin{array}{l}K = \;0 \quad\; 1 \quad\;\; 2 \quad\;\; 3 \quad\;\; 4 \quad\;\; 5 \quad\;\;\; 6 \quad\;\;\; 7 \quad\;\;\; 8 \quad\;\;\; 9\\ R = \ldots 5 \ldots 10 \ldots 20 \ldots 40 \ldots 70 \ldots 120 \ldots 200 \ldots 330 \ldots 500 \ldots \gamma\end{array}$$

Table 1 is extracted from that for eight stations by Bartels, Heck, and Johnston [3] and includes, in addition, values for Dombås.

Index K for Dombås—The scales adopted for Dombås (latitude 62° 04′.7 north, longitude 9° 05′.8 east) in determining K for each of the eight daily three-hour intervals in 1939, 1940, and 1941, are published in "Publikajoner fra Det Norske Institutt for Kosmisk Fysikk" [No. 22] and those for 1942 will appear in the next issue of that yearbook. Tables 2 to 4 summarize particulars of mean values and frequencies of K at Dombås for the years 1939-42 and are shown graphically





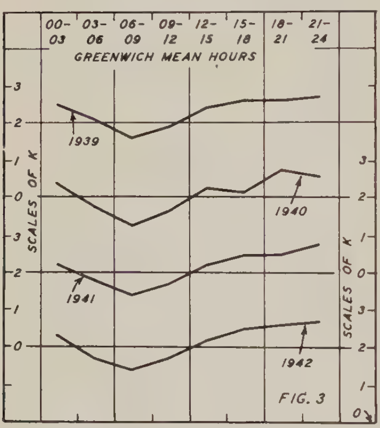


FIG. 1—ANNUAL MEAN FREQUENCY-DISTRIBUTION OF THREE-HOUR-RANGE INDEX K, DOMBÅS, FOR YEARS 1939–42

FIG. 2—COMPARISON OF FREQUENCY OF VARIOUS VALUES OF INDEX K AT DOMBÅS, SITKA, CHELTENHAM, AND HONOLULU, DURING 1939

FIG. 3—DIURNAL VARIATION OF THREE-HOUR-RANGE INDEX K, DOMBÅS, FOR YEARS 1939–42

in Figures 1 to 4. Figure 2 shows also, for comparison, corresponding graphs for Sitka, Cheltenham, and Honolulu.

The values for monthly means for K in Table 3 are calculated by aid of the frequency-tables. Each figure for frequency is multiplied by the

TABLE 1—*Lower limits of ranges R for three-hour indices K*

Observatory	Latitude	Lower limit of R for K									
		0	1	2	3	4	5	6	7	8	9
	°	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Sitka	60	0	10	20	40	80	140	240	400	660	1000
Dombås	62	0	8	15	30	60	105	180	300	500	750
Cheltenham	50	0	5	10	20	40	70	120	200	330	500
Honolulu	21	0	3	6	12	24	40	70	120	200	300

TABLE 2—*Annual mean values of K for each of the eight daily GMT three-hour intervals, Dombås, 1939-42*

Year	Mean K for GMT three-hour interval								Annual mean K
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	
	γ	γ	γ	γ	γ	γ	γ	γ	γ
1939	2.5	2.1	1.6	1.9	2.4	2.6	2.6	2.7	2.3
1940	2.4	1.8	1.3	1.7	2.3	2.2	2.8	2.6	2.1
1941	2.2	1.8	1.4	1.7	2.2	2.5	2.5	2.8	2.1
1942	2.3	1.7	1.4	1.7	2.2	2.5	2.6	2.7	2.1

TABLE 3—*Annual mean number of indices for values of K from 0 to 9, Dombås, 1939-42*

Year	Number for $K=$										Sum	Annual mean K
	0	1	2	3	4	5	6	7	8	9		
												γ
1939	50	32	58	50	25	13	6	4	2	2	243	2.32
1940	54	35	62	48	23	10	4	3	2	1	244	2.15
1941	48	44	64	48	20	9	4	4	1	1	243	2.13
1942	48	42	63	48	24	12	4	2	1	0	243	2.11

index-figure above and the totals are divided by the sums entered in the second-last column.

The graphs in Figure 4 are plotted from the values given in Table 4. Each index-figure between 0 and 9 is represented with a number of vertical lines corresponding to the index-figures themselves. Thus, for April and July, 1939, where all the indices between 0 and 9 occurred, index "0" is drawn with a single and broken vertical line, index "1" with a single full line, index "2" with two full lines, etc., and the vertical length of each line corresponds to the percentage-figure given. The world-wide value of K, that is, K_w, for the year 1939 [6] is reproduced in Figure 5; it shows comparatively good agreement with the results at Dombås for the same year.

Bartels, Heck, and Johnston [3] also introduced a second index designated B. This was done because the scale of 0 to 9 for K sometimes is not sufficiently detailed for the study of certain phenomena—for example, the daily variation for which it is desirable to characterize a day by a single index rather than by a series of interval-indices. The index B involves a finer division of the scale 0 to 9 through half-units but at Dombås the index AS or S, regularly determined, is well suited for the study of special phenomena.

To explain in more detail, consider extreme cases, as listed in Table 5, for which the actual three-hour ranges have been rated as zero for all three elements in determining K. The table shows totals of 37, 70, 9, and 12 cases for the years 1939, 1940, 1941, and 1942, respectively; it is doubtful that there should be 70 cases in 1940 and only 9 in 1941. It is to be recalled that the material is compiled at one time for half-

year periods and this judgment, as to when quiet conditions prevail and R is taken as zero, may be prejudiced.

Consider next Table 6 which shows the annual distribution of frequency for $K=0$ at Dombås, that is, when R is between 0 and 8γ. Here the scale-values of the variometers have a certain interest; they were 7.1, 5.8, and 6.0 γ/mm for D, H, and Z, respectively.

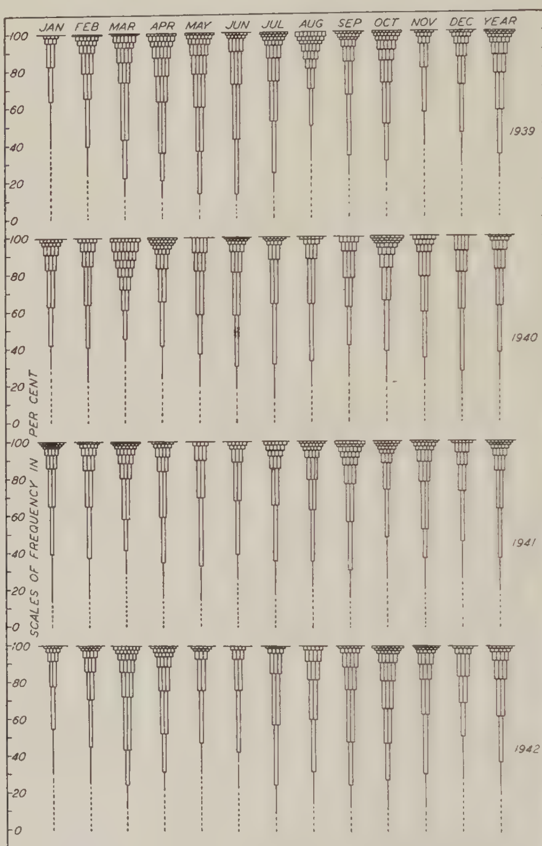


FIG. 4—MONTHLY AND ANNUAL PERCENTAGE FREQUENCY-DISTRIBUTION OF THREE-HOUR-RANGE INDEX K, DOMBÅS, FOR YEARS 1939-42 (GREENWICH MEAN HOURS)

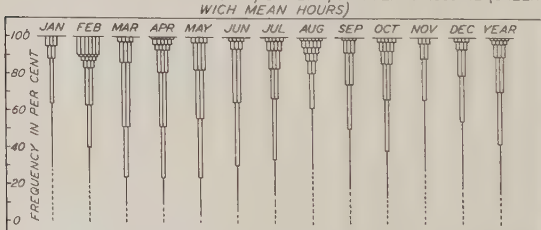


FIG. 5—MONTHLY AND ANNUAL PERCENTAGE FREQUENCY-DISTRIBUTION OF WORLD-WIDE THREE-HOUR-RANGE INDEX K_W, 1939 (GREENWICH MEAN HOURS)

TABLE 4—*Monthly and annual frequencies in per cent of total for K, Dombås, 1939-42*

Year	Month	Frequency-percentage for $K=$									
		0	1	2	3	4	5	6	7	8	9
1939	Jan.	38	25	19	13	3	2	0	0	0	0
	Feb.	23	16	26	14	11	4	3	2	0	1
	Mar.	11	10	21	31	11	8	3	4	1	0
	Apr.	10	10	15	28	14	10	6	3	3	1
	May	6	7	24	24	17	10	6	3	2	1
	June	5	7	30	30	18	7	1	2	0	0
	July	13	11	28	22	12	7	3	2	1	1
	Aug.	30	19	20	11	5	4	5	1	2	3
	Sep.	22	11	33	18	8	4	1	2	1	0
	Oct.	20	10	20	22	12	6	5	2	2	1
	Nov.	38	18	24	13	4	2	1	0	0	0
	Dec.	27	18	26	15	7	4	2	1	0	0
	Year	20	13	24	20	10	6	3	2	1	1
1940	Jan.	30	12	21	20	8	5	2	2	0	0
	Feb.	22	19	23	21	8	5	2	0	0	0
	Mar.	33	12	16	11	7	5	4	5	5	2
	Apr.	23	18	24	18	8	3	2	1	2	1
	May	20	17	21	24	10	8	0	0	0	0
	June	18	12	28	23	11	4	2	1	1	0
	July	12	19	33	24	8	2	1	1	0	0
	Aug.	19	14	31	24	8	3	0	1	0	0
	Sep.	24	17	21	16	14	5	3	0	0	0
	Oct.	27	12	27	17	7	4	3	1	1	1
	Nov.	22	12	25	19	13	4	3	2	0	0
	Dec.	14	13	33	20	12	8	0	0	0	0
	Year	22	15	25	20	10	5	2	1	0	0
1941	Jan.	13*	26*	26*	21*	7*	4*	1*	1*	1*	0*
	Feb.	15*	22*	28*	20*	8*	4*	2*	1*	0*	0*
	Mar.	28*	13*	17*	22*	8*	5*	3*	2*	1*	1*
	Apr.	15	19	25	25	8	5	2	1	0	0
	May	14	19	37	20	8	2	0	0	0	0
	June	26	13	29	21	7	2	2	0	0	0
	July	17	18	30	20	7	3	3	2	0	0
	Aug.	21	14	28	16	12	4	2	2	1	0
	Sep.	15	15	26	21	10	4	3	3	1	2
	Oct.	26	23	26	14	5	2	2	1	1	0
	Nov.	20	17	20	21	11	6	2	2	1	0
	Dec.	26	20	27	14	7	5	0	1	0	0
	Year	19	18	27	20	8	4	2	1	1	0
1942	Jan.	30	25	23	14	5	2	1	0	0	0
	Feb.	25	20	26	15	8	4	1	1	0	0
	Mar.	12	13	19	29	13	7	3	2	2	0
	Apr.	22	10	21	23	13	6	2	2	1	0
	May	31	17	28	17	5	2	0	0	0	0
	June	23	20	33	17	5	2	0	0	0	0
	July	10	15	33	27	11	3	1	0	0	0
	Aug.	15	17	28	22	10	6	2	0	0	0
	Sep.	12	12	24	28	12	8	3	1	0	0
	Oct.	12	15	20	19	15	10	5	2	1	1
	Nov.	13	18	32	19	8	6	2	1	1	0
	Dec.	29	23	18	14	12	3	1	0	0	0
	Year	20	17	25	20	10	5	2	1	0	0

*Interpolated values, with aid of data supplied by Rude Skov Observatory, because of lack of photographic paper for registrations at Dombås during January to March 1941.

Table 5—*Cases for which three-hour-range R was taken as zero, Dombås, 1939-42*

Date	No. cases	Date	No. cases	Date	No. cases	Date	No. cases	Date	No. cases
1939		*1939*		*1940*		*1940*		*1941*	
Jan. 3	1	Nov. 22	3	Mar. 4	3	Sep. 13	1	May 1	3
4	4	Dec. 18	2	5	2	18	2	Aug. 22	1
24	1	19	4	6	2	23	1	Dec. 11	2
26	2	20	4	7	1	Oct. 24	1	*1942*	
27	5	*1940*		12	2	25	1	Jan. 1	1
28	2	Jan. 21	1	15	3	Nov. 2	2	8	1
Feb. 21	1	22	1	16	2	10	4	14	1
Apr. 16	1	23	2	17	2	11	3	29	2
Aug. 6	1	26	3	18	4	20	1	Feb. 1	1
9	1	28	1	Apr. 10	1	Dec. 8	6	14	1
18	1	29	2	May 6	2	9	1	Apr. 22	1
Sep. 29	1	Feb. 10	1	30	1	*1941*		May 12	1
Nov. 8	1	18	2	Aug. 24	1	Feb. 1	1	20	1
19	1	19	2	25	3	27	1	27	1
21	1	Mar. 1	1	Sep. 11	2	Mar. 27	1	Dec. 31	1

Table 6—*Monthly and annual frequency-distribution for $K=0$, Dombås, 1939-42*

Year	Cases in month of												Sum	Mean
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.		
1939	95	51	27	25	13	11	32	75	52	49	92	67	589	50
1940	74	50	83	56	49	43	30	46	57	66	51	35	640	53
1941	52*	45*	39*	36	34	61	43	52	37	63	47	64	573	48
1942	75	57	29	53	77	56	27	37	28	31	32	73	575	48
Sum	296	203	178	170	173	171	132	210	174	209	222	239	2377	199
Mean	74	51	44	42	43	42	33	52	43	52	55	60	594	50

*Interpolated.

Table 7 summarizes the number of cases for each GMT three-hour interval for which $K=0$ at Dombås during 1939-42. It will be seen from Tables 6 and 7 that the variations of the total number of cases with $K=0$ is a little greater for 1940 but practically the same for the other three years.

Table 7—*Frequency-distribution of $K=0$ for each GMT three-hour-interval, Dombås, 1939-42*

Year	Number of cases in GMT three-hour interval								Sum	Mean
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24		
1939	80	89	118	70	52	52	63	65	589	74
1940	76	109	139	86	53	57	57	63	640	80
1941	69	92	127	74	56	45	58	52	573	72
1942	72	99	123	78	49	47	52	55	575	72
Sum	297	389	507	308	210	201	230	235	2377	298
Mean	74	97	127	77	52	50	58	59	594	74

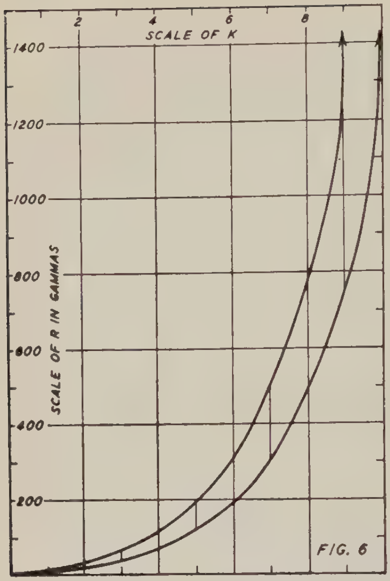
TABLE 8—*Values of R exceeding lower limit of 750γ for GMT three-hour intervals, Dombås, 1939-42*

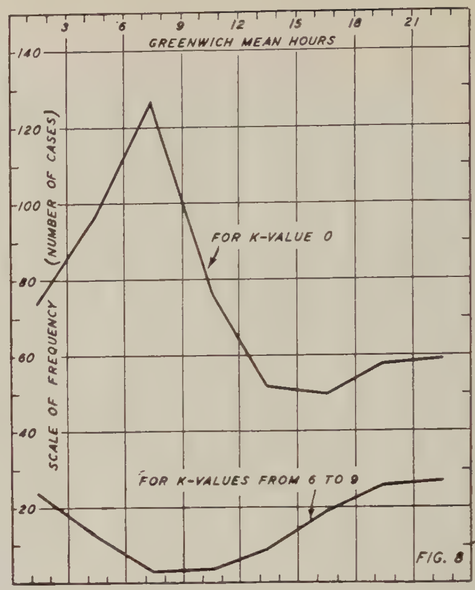
Date	Values of R which exceeded 750γ for GMT three-hour interval							
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
1939								
Feb. 24	....	....	....	....	....	....	1100	952
25	1090	....	....	....	....	....	....	....
Apr. 27	....	....	....	....	....	....	....	1060
May 1	....	....	....	....	....	....	762	....
7	1010	....	....	....	....	....	....	....
July 4	....	....	....	....	....	....	....	914
Aug. 12	828	....	....	....	....	....	....	....
22	1238	....	....	....	....	....	1240	....
23	880	....	....	....	....	....	....	....
Oct. 15	785	....	....	....	....	....	....	....
1940								
Jan. 3	....	....	....	....	....	810	....	....
Mar. 23	....	....	....	....	....	....	....	1055
24	877	....	....	....	....	....	760	....
29	....	....	....	....	....	960	....	....
31	1025	....	....	....	....	....	....	1080
Apr. 3	854	795	....	....	....	....	....	....
June 25	....	....	....	....	957	900	....	....
26	....	....	....	....	....	....	1090	....
27	1020	....	....	....	....	....	....	....
Oct. 1	....	....	....	....	....	....	1220	....
7	....	....	....	....	....	....	860	....
1941								
Sep. 18	....	....	....	....	....	....	805	775
19	....	....	800	....	....	....	838	....
1942								
Mar. 2	813	....	....	....	....	....	....	....
Apr. 4	....	....	....	....	....	....	843	....
Oct. 28	....	....	....	....	....	....	1070	....

TABLE 9—*Total number of cases where R exceeded lower limit of 750γ for GMT three-hour intervals, Dombås, 1939-42*

Year	GMT three-hour interval								Sum
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	
1939	6	0	0	0	0	0	3	3	12
1940	4	1	0	0	1	3	4	2	15
1941	0	0	1	0	0	0	2	1	4
1942	1	0	0	0	0	0	2	0	3
Sum	11	1	1	0	1	3	11	6	34

The adopted relation between R and K at Dombås is shown by Figure 6; according to this for every case in which R is greater than 750γ,





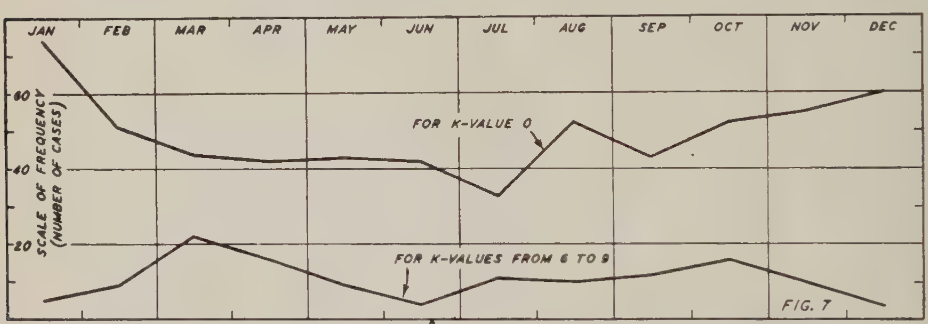


FIG. 6—RELATION BETWEEN K AND R, DOMBÅS
FIG. 7—MEAN ANNUAL FREQUENCY FOR THREE-HOUR-RANGE INDEX K, DOMBÅS, 1939-42
FIG. 8—MEAN DIURNAL VARIATION OF FREQUENCY FOR THREE-HOUR-RANGE INDEX K, DOMBÅS, FOR YEARS 1939-42

K is designated as 9. If R exceeds 1200γ, however, an extra value for $K=10$ may be added. This was actually the case for three cases during 1939-42, namely, August 22, 1939 (00^h-03^h and 18^h-21^h) and October 1, 1940 (18^h-21^h). As might be expected, practically all cases of extremely great disturbance were between 15^h and 03^h with the greatest during 18^h to 21^h.

According to Bartels, Heck, and Johnston [3] the occurrence of great storms is found for values of $K=6$ or more. The annual and monthly frequency-distribution and diurnal variation for values of $K=6$ or more at Dombås during 1939-42 are summarized in Tables 10 and 11 and by Figures 7 and 8.

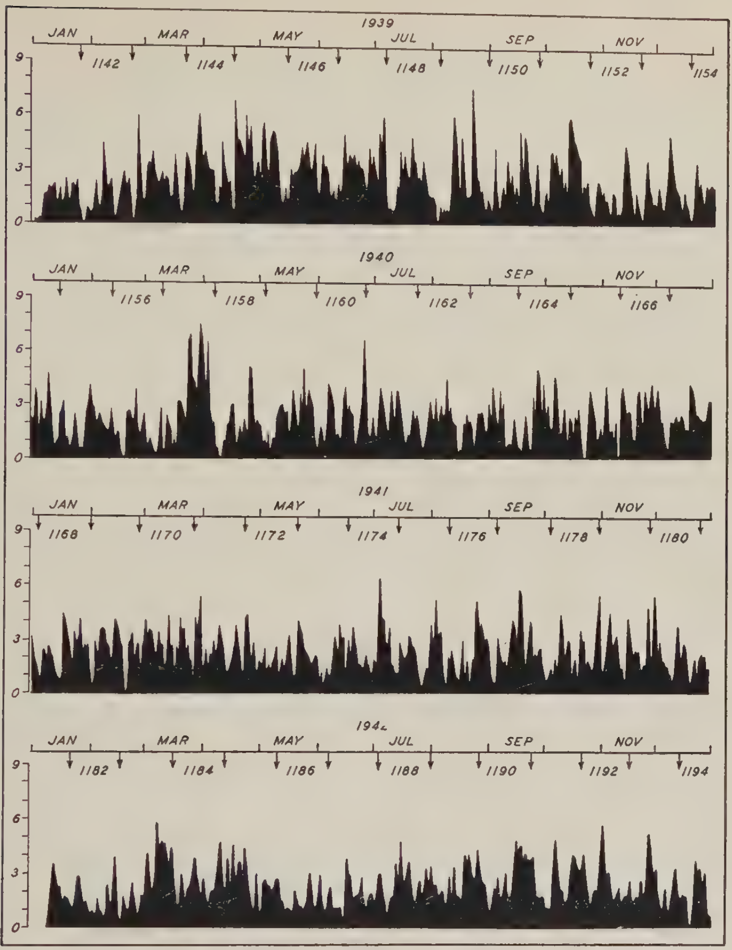


FIG. 9—RECURRENCE-TENDENCY OF MAGNETIC ACTIVITY FOR EACH SOLAR ROTATION PERIOD AS EXPRESSED BY THREE-HOUR-RANGE INDEX K, DOMBÅS, 1939-42 (GREENWICH MEAN HOURS)

TABLE 10—*Monthly and annual frequency-distribution of K = 6 or more, Dombås, 1939-42*

Year	Number of cases for month of												Sum	Mean
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.		
1939	0	13	18	30	26	2	16	20	10	25	4	5	169	16
1940	9	6	39	15	5	11	7	3	9	12	14	1	131	11
1941	7	7	12	6	1	5	15	13	19	11	12	4	112	9
1942	3	8	18	12	2	0	5	3	8	18	8	4	89	7
Sum	19	34	87	63	34	18	43	39	46	66	38	14	501	43
Mean	5	9	22	16	9	4	11	10	12	16	10	4	125	11

TABLE 11—*Diurnal variation in frequency-distribution of $K=6$ or more, Dombås, 1939-42*

Year	Number of cases for which $K=6$ or more for GMT three-hour interval								Sum	Mean
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24		
1939	33	19	6	5	16	27	28	36	169	21
1940	21	13	5	5	9	17	35	26	131	16
1941	24	9	2	2	9	16	26	24	112	14
1942	18	9	1	3	3	17	17	21	89	11
Sum	96	50	14	15	37	77	106	107	501	62
Mean	24	12	3	4	9	19	26	27	125	16

Sunspot-frequency and 27-day period—The well-known recurrence-tendency of geophysical elements of high and low values according to the solar rotation-period of 27 days is confirmed by the data for magnetic activity at Dombås.

The systematic observations of sunspot-numbers, R, according to Wolf [9], after the relation $R=k(10g+f)$, was started in 1849. To make some allowance for the area of the spots and avoid having a small spot of short duration count as a large group, Wolf put the arbitrary figure 10 before g in the formula, where g and f are the group and total spot-numbers, respectively, and k is a constant depending on the type of telescope and other factors affecting the observations. R thus represents a relative frequency-number for sunspot-activity. In Figure 9 the 27-day periods are marked by short vertical arrows and are numbered, beginning with 1141 in January 1939, in accordance with Brunner's yearly reports [9].

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DET MAGNETISKE BYRÅ,
Bergen, Norway, April 1, 1943

FINAL RELATIVE SUNSPOT-NUMBERS FOR 1942

By W. Brunner

Table 1 contains the final sunspot-numbers for 1942, for the whole disc of the Sun, based on observations made at the Zürich Observatory, supplemented by series furnished by other cooperating observatories

Table 1—*Final relative sunspot-numbers for the whole disc of the Sun for 1942*

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	46	27*	127	39	51	0	0	21	15	14	54	61
2	41[d]	35*	116	35	28	8	*M*18[c]	11	0	17	61[ab]	56
3	*E*34*[c]	*M*41[cca]	56	41	30	8	19[a]	*E*22[ac]	*M*28[c]	8	49	46*
4	39[d]	67*[a]	32	30[d]	31	8	*E*24[c]	23	21	0	40	35
5	67*	77*	31*	32	27[a]	0	49	24*	20	0	28	31*
6	*E*58*[ac]	*M*82*[c]	20	17	25	*M*14[ac]	50	20	14	0	33*	*E*15[cd]
7	57*[a]	79	7	*E*25[c]	25[d]	15	43[a]	19	26*	18	31	31
8	81	48*	10*	28*	20	13	34	28[a]	15	17	27*	31
9	83[a]	39*	0	36[b]	25[d]	10	31	18	14	27	*M*22[c]	26
10	60*[aa]	34[d]	7*	33	29[d]	8	19	12	15	*W*32[cd]	25	31[a]
11	61*	23*[d]	15	44[d]	34*	7	16	8	7	29	22[a]	29
12	48	46	18*	*E*57[cc]	31	0	10	0	10	32	21	25
13	50[d]	46*	*E*17[c]	59	40[a]	0	29	7	26[d]	10*	24*	24*[a]
14	37*	44	25	67	54	10	0	7	33	9	25*	25
15	31	52	26[ad]	60	39*[a]	8	*E*19[c]	7	32	11[a]	20*	25
16	23*	37	29	69[ab]	52[ad]	8[d]	19	17	16	12	8	15
17	15*	38[aa]	38[d]	71[a]	46	10	18	8	8	10	0	9*
18	21*[d]	37*	53	*E*84[cc]	35	14	8	7	8	10*	0	8
19	22*[a]	*EM*40[cc]	*E*65[c]	*M*109[cd]	34	*M*31[c]	7	0	8[a]	17*	0	7
20	18	52*	72	105	26	25	*W*15*[c]	10[d]	15	19	7*	7
21	25*	47	83[ad]	94	14	28[a]	13	28	*E*25[c]	23*	*E*30*[cd]	7
22	24*	41[d]	102	94[ab]	11[a]	19[a]	11	27	22*	25*	31	*M*13*[c]
23	*M*31[c]	53	117[aa]	82	9	17	0	*M*47[ac]	21	17*	48[d]	27
24	31*	*M*65[ac]	106*	85	8	15	0	34	11	16	39[a]	22*
25	31	68*	100	59[a]	8	20	0	36	*M*20[ac]	8	37	20*
26	10	84*	115	*E*79[c]	15	14	8	47[ad]	21*	*E*13[c]	37*	17*
27	8	82*[a]	79[b]	*EM*89[cc]	7	*W*20[c]	8	43	14*	31[dd]	47*	12*
28	0	93*[b]	48	73	15	11	17[d]	34	21	39[a]	33*[b]	11
29	11[d]		51*[d]	65*[d]	0	0	23	26	16	37	*M*56*[ac]	11[a]
30	22		61	61[a]	0	0	25	19	15	51	66*[d]	11
31	20		55		7		17	17		44		11
Mean	35.6	52.8	54.2	60.7	25.0	11.4	17.7	20.2	17.2	19.2	30.7	22.5

[a] Passage of an average-sized group through the central meridian.
[b] Passage of a large group or spot through the central meridian.
[c] New formation of a center of activity: *E*, on the eastern part of the Sun's disk; *W*, on the western art; *M*, in the central-circle zone.
[d] Entrance of a large or average-sized center of activity on the east limb.

for days (indicated by asterisks) on which no observations were possible at Zürich.

Table 2 gives the yearly means of the relative numbers, *R*, since the last minimum 1933 and the number of days without spots.

Table 2—*Yearly means of relative sunspot-numbers, R*

Year	*R*	Increase	No. spotless days
1933	5.7		240
1934	8.7	3.0	154
1935	36.1	27.4	20
1936	79.7	43.6	0
1937	114.4	34.7	0
1938	109.6	− 4.8	0
1939	88.8	−20.8	0
1940	67.8	−21.0	0
1941	47.5	−20.3	5
1942	30.6	−16.9	23

Figure 1 gives a graphical representation of the daily relative sunspot-numbers for 1942, the times being plotted as abscissas and the relative numbers as ordinates. The limits of the successive solar rotations are indicated by vertical arrows in the upper edge of the Figure. The secondary maxima and minima succeeding the rotation-periods do not represent real fluctuations in sunspot-activity, but are rather to be attributed to the influence of solar rotation, to a certain stability of the centers of activity for spots, and to the special distribution of these centers of activity in the direction of rotation.

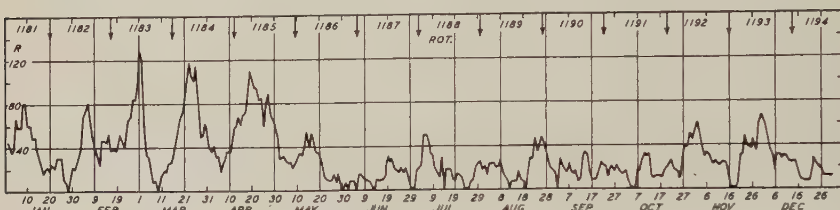

FIG. 1—DAILY RELATIVE SUNSPOT-NUMBERS FOR 1942

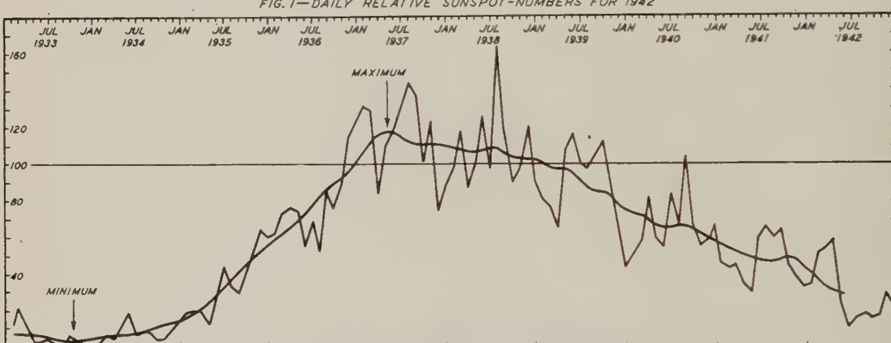

FIG. 2—OBSERVED AND SMOOTHED MONTHLY RELATIVE NUMBERS FOR 1933 TO 1942

Figure 2 shows the observed and smoothed monthly relative numbers for 1933 to 1942. The purpose of smoothing is to eliminate the secondary variations. The method of smoothing is as follows: For obtaining the mean of the epoch July 1, the average of the monthly means of the twelve months January to December is taken (m_1), and for the epoch August 1, the average of the monthly means for February to January (m_2). The mean of these $m=(m_1+m_2)/2$, which represents the smoothed relative number for the middle of July, is used for the construction of the curve.

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Zürich, Switzerland

AMERICAN MAGNETIC CHARACTER-FIGURE, C_A, THREE-HOUR-RANGE INDICES, K, AND MEAN K-INDICES, K_A, FOR APRIL TO JUNE, 1943

By H. F. Johnston

Summaries of American *URSI* broadcasts have appeared regularly in this Journal since the issue for December, 1930.

As set forth in this Journal for June, 1937, "The Department of Terrestrial Magnetism and the United States Coast and Geodetic Survey with the cooperation of the United States Army and the United States Navy communication-services and several amateur radio stations have undertaken to supply the American character-figure based upon the reports of the seven American-operated observatories—those of the Department of Terrestrial Magnetism at Huancayo in Peru and at Watheroo in Western Australia, and those of the United States Coast and Geodetic

Table 1—*American magnetic character-figure C_A for Greenwich half- and full-days based on reports from Cheltenham. Honolulu, Huancayo, San Juan, Sitka, Tucson, and Watheroo for April to June, 1943*

Day	April			May			June		
	0^h-12^h	12^h-24^h	0^h-24^h	0^h-12^h	12^h-24^h	0^h-24^h	0^h-12^h	12^h-24^h	0^h-24^h
1	0.6	0.3	0.5	1.4	0.9	1.2	0.3	0.4	0.3
2	0.5	0.6	0.5	1.0	0.6	0.8	0.1	0.1	0.1
3	1.2	0.6	0.9	0.1	0.6	0.3	0.0	0.0	0.0
4	0.6	0.6	0.6	0.6	0.4	0.5	0.0	0.0	0.0
5	0.6	0.8	0.7	0.4	0.4	0.4	0.0	0.1	0.1
6	0.8	0.7	0.8	0.1	0.1	0.1	0.7	0.0	0.4
7	0.6	0.5	0.6	0.1	0.0	0.0	0.2	0.5	0.4
8	0.4	0.0	0.2	0.0	0.0	0.0	1.2	0.9	1.1
9	0.0	0.1	0.1	0.0	0.0	0.0	1.1	0.6	0.9
10	0.9	0.6	0.8	0.1	0.4	0.3	0.9	0.5	0.7
11	1.3	0.4	0.8	0.1	0.6	0.3	0.4	0.6	0.5
12	0.0	0.0	0.0	0.8	0.2	0.5	0.7	0.6	0.6
13	0.0	0.0	0.0	0.8	0.6	0.7	0.9	0.7	0.8
14	0.0	0.0	0.0	0.6	0.3	0.5	0.7	0.1	0.4
15	0.1	0.6	0.3	1.3	0.4	0.9	0.0	0.0	0.0
16	0.9	0.4	0.6	0.2	0.8	0.5	0.0	0.0	0.0
17	0.4	0.3	0.3	0.6	0.7	0.7	0.0	0.0	0.0
18	0.4	0.0	0.2	1.3	0.6	0.9	0.0	0.0	0.0
19	0.0	0.0	0.0	0.9	0.6	0.8	0.1	0.7	0.4
20	0.2	0.6	0.4	0.1	0.1	0.1	1.0	0.6	0.8
21	1.0	0.8	0.9	0.0	0.0	0.0	0.9	0.6	0.8
22	0.4	0.0	0.2	0.0	0.0	0.0	0.9	0.6	0.8
23	0.0	0.0	0.0	0.4	0.4	0.4	0.8	0.9	0.9
24	0.0	0.0	0.0	1.0	0.9	0.9	1.0	0.6	0.8
25	0.5	0.6	0.5	0.9	0.7	0.8	0.8	0.4	0.6
26	1.2	0.5	0.9	0.4	0.4	0.4	0.1	0.1	0.1
27	0.1	0.1	0.1	0.7	0.5	0.6	0.1	0.2	0.1
28	0.0	0.5	0.2	1.1	0.6	0.9	1.0	0.6	0.8
29	0.6	0.1	0.4	0.9	0.2	0.6	0.4	0.0	0.2
30	1.0	0.6	0.8	0.5	0.1	0.3	0.1	0.0	0.0
31				0.0	0.1	0.0			
Means	0.5	0.3	0.4	0.5	0.4	0.5	0.5	0.3	0.4

Table 2--Three-hour-range indices, K, April to June 1943

April 1943

	1	2	3	4	5	6	7	8
Si	2435 3322	2343 4423	4556 4333	4345 5332	4334 3532	3156 6522	3343 4222	3243 3111
Ch	4422 2323	4340 2324	6454 2334	3432 3233	6332 2424	4234 4434	5533 3232	3243 2112
Tu	4423 2222	4251 3224	5554 2434	4433 3432	5334 2534	4245 5333	4533 3233	2242 1121
SJ	4322 1012	3230 1013	5343 1322	3411 3122	5412 2423	3223 3222	3323 3131	2131 1000
Ho	3223 2111	3141 1213	5444 1313	3233 2212	3113 2423	3224 3122	4232 3121	1132 0010
Hu	2333 2133	2231 3233	5432 3432	3422 4333	5322 3543	3223 3432	3323 4322	2223 2221
Wa	2223 2331	3232 4323	5445 4543	3233 5442	2223 3533	2245 5433	3222 4333	2232 1111

	9	10	11	12	13	14	15	16
Si	1100 1021	1477 7233	4787 4232	2012 2110	1121 1111	0100 2111	1113 3233	3345 3222
Ch	1100 1133	1444 3234	5564 3233	2111 1121	0121 0102	1111 1012	1122 2234	2344 3232
Tu	0100 2132	2444 3244	5565 2332	2122 2122	1130 0101	1121 1122	1123 2333	3344 2232
SJ	0001 1121	1223 3343	3443 0122	1021 1000	0120 0000	0000 0100	0022 1132	2232 2121
Ho	0000 1121	0243 2123	3455 1211	0111 1011	0010 0101	0010 0000	0012 2123	2243 2121
Hu	1111 3231	2223 4332	3433 2432	1121 2210	0110 1320	1010 1221	0022 3443	2232 3332
Wa	1101 1111	1254 5444	2332 2121	2112 2111	1111 2211	1121 2221	1133 3233	3433 3332

	17	18	19	20	21	22	23	24
Si	2143 2212	2321 2211	2201 1210	0125 5213	3546 5522	2244 1211	0111 0111	1101 1011
Ch	2242 2223	2421 1222	3311 2121	0222 3323	4433 3233	1344 1211	0111 0111	1110 1111
Tu	2143 2212	1432 1112	3211 1021	0222 2323	4444 3333	1344 2222	0111 0112	1111 2101
SJ	1121 1111	1412 1111	2201 1021	0102 2212	4433 2131	0332 1110	0010 1100	0110 0001
Ho	1133 0111	0312 1111	1100 1001	0002 2023	3324 2221	0123 0111	0001 0000	0001 0012
Hu	2122 3321	0321 1221	1101 3130	0112 2421	3333 4442	1222 2220	1111 2220	0100 3211
Wa	1232 2222	1312 1111	2111 2111	1213 3423	3334 4242	2232 1111	1112 1111	1111 1102

	25	26	27	28	29	30
Si	2242 3323	7785 4222	2220 3310	1220 0123	3244 2322	3535 3333
Ch	3331 1244	5564 2223	5120 1210	2220 0134	4243 2123	3535 2223
Tu	3332 2234	6554 3323	3220 1210	1220 0244	3243 1113	3545 3233
SJ	3221 0335	5441 1112	3010 0100	1210 0134	3232 1112	3333 1223
Ho	1121 1232	3334 1112	2110 1000	0100 0133	2233 0111	2333 1122
Hu	2222 3332	4432 4322	3110 3311	2210 2233	3222 3223	3433 4323
Wa	2232 1333	5334 4343	2211 3221	1110 2234	2234 2343	3335 3242

May 1943

	1	2	3	4	5	6	7	8
Si	4797 5553	4466 4422	2112 3322	2432 2112	2243 3322	2102 2211	2221 2111	1100 1211
Ch	4554 3345	5434 2322	4201 1224	2421 1232	2132 2222	3102 2212	3311 1122	1000 1111
Tu	5455 3445	5444 3333	3122 1224	3432 2232	2242 3221	3112 2321	3321 1012	1100 2132
SJ	4444 3135	4322 2311	3110 1123	2321 1122	2122 2220	2102 0101	3311 0021	0000 1010
Ho	3355 3333	4244 1311	1010 1113	1221 0132	2112 2110	2101 1101	1211 1111	0000 0011
Hu	4433 3343	4322 3321	3110 1323	2221 2322	2133 3331	1101 2311	2201 2210	1001 3210
Wa	5456 5554	4365 4532	3123 4435	3432 2233	1233 3222	3223 3321	2223 1212	1111 1112

	9	10	11	12	13	14	15	16
Si	1121 2111	1012 2211	1210 1323	3352 2122	2265 4322	3234 3222	6666 5223	1026 6332
Ch	1210 1112	1112 2222	1221 1333	3541 1133	3343 4333	5423 2224	5553 1134	1113 3343
Tu	0221 1111	1222 3221	1321 2333	3541 2122	3344 3423	4423 2133	6544 3223	1123 4343
SJ	1200 0010	2011 2221	2220 1322	3332 1123	2242 2222	3312 1111	5432 2112	0013 2232
Ho	0010 0100	0111 2220	1220 2222	2430 0122	2243 2211	2112 1001	5434 2012	0012 2231
Hu	0111 1220	1022 3331	1211 3322	3321 2222	2233 4421	3322 2221	5432 2222	0123 3432
Wa	1221 1111	1121 2322	1221 2322	2332 1122	2243 3323	3233 2233	5445 4333	1234 4443

	17	18	19	20	21	22	23	24
Si	3344 2334	5666 5333	3453 4233	3223 3122	1223 2200	1121 1101	1225 4223	6434 4333
Ch	3344 3345	6644 3234	5552 3233	3112 2122	1222 1110	1122 1113	1333 2234	6433 3344
Tu	3353 3345	5564 3334	4552 3244	3112 1111	2133 2221	1120 1002	1334 0212	5323 1334
SJ	2233 2333	4433 3123	3343 2032	2101 1001	1112 1110	1221 1101	1233 2113	4322 1323
Ho	2233 2233	3353 2113	3431 3021	1002 2000	1021 1110	0101 1000	1113 0101	5513 3232
Hu	2222 3432	4323 3433	2332 3332	2101 1111	0112 2310	0120 1101	0223 2321	3221 3432
Wa	2333 2443	5455 4334	3443 4353	2223 2222	1122 1211	1111 2221	1223 2233	3432 4543

	25	26	27	28	29	30	31
Si	4354 5322	3212 3222	3352 2223	5555 3433	3544 3221	3241 2122	2122 2112
Ch	4342 4334	3322 1233	4431 1233	5443 3334	3433 2232	3331 1233	1221 1223
Tu	5342 3112	3112 0122	3441 0223	4543 2232	3444 2121	3242 1222	2222 2213
SJ	4341 3222	3211 0122	4320 0222	4432 2133	2422 1120	2131 1121	1121 0121
Ho	3133 2211	1211 1112	2341 0122	4343 2222	2333 2110	2130 0010	1112 1111
Hu	3332 4322	2111 2332	3321 2322	3433 3332	2322 2220	2231 2321	1211 2221
Wa	3345 4443	2222 3334	3332 2334	4334 3433	3433 3232	2342 2322	1122 2322

¨Interpolated.

Table 2--Three-hour-range indices, K, April to June 1943--concluded

June 1943

	1	2	3	4	5	6	7	8
Si	2233 3222	2225 5121	1131 1211	2221 2200	2111 3221	4522 2211	1215 5222	3456 5534
Ch	2222 1233	2123 2222	1121 1223	2221 1111	1111 2222	3442 2213	1113 2334	3445 3334
Tu	2233 2233	2123 3212	2122 2213	2221 2121	2211 2113	4543 2222	2123 2323	4545 4334
SJ	1211 1122	1112 1001	0011 1101	0101 1000	1110 2211	3342 2110	1012 2222	3434 3323
Ho	1212 1022	1113 1001	0010 1000	1101 1000	2001 1111	1342 2101	0111 2112	3425 3223
Hu	1111 2222	1112 2220	1010 2211	0111 2100	1100 3221	3332 3201	1112 3422	2423 5433
Wa	1222 2223	2124 3121	2121 1121	1112 1101	1111 1232	2342 2111	1124 3222	2535 5433
	9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Si	3545 4332	2356 3423	1134 4322	2355 3222	4432 4332	3434 3221	0321 1111	2111 2211
Ch	4455 3343	2444 2334	2123 3323	1443 3233	6422 3343	4433 2222	1321 1122	1201 1112
Tu	4545 3332	2555 2424	2133 3323	2442 3233	5533 3333	4434 2331	2321 1012	1111 0112
SJ	3443 2222	1333 1312	1023 2222	1232 2122	4322 2132	3332 2110	0210 0011	0100 0100
Ho	2334 2011	0244 1113	0122 2212	1242 1121	5322 3122	3323 0110	1110 0010	1000 0000
Hu	3423 3331	1222 3322	2123 4522	2222 3331	3312 3432	2221 2310	0200 0111	0100 0210
Wa	3445 3332	1336 2423	2124 4423	2433 3343	4333 4333	3333 3211	1111 1111	1111 1111
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Si	2210 1100	1121 2111	2214 3324	5534 2223	4445 4333	3563 4332	4443 5333	4564 4333
Ch	2200 1121	0112 1112	1213 3445	4623 3334	4334 3334	4553 2333	3443 4444	4553 2343
Tu	3110 0011	0121 1121	2223 2445	4534 2233	4335 3333	3553 3332	4543 4334	4544 3453
SJ	1100 0000	0000 0002	1112 2223	4423 2223	3223 2233	2432 1212	3332 2334	4432 2232
Ho	1100 0000	0000 0001	0012 1223	3323 2212	3233 2221	1242 2111	2322 3322	2444 2112
Hu	1100 1100	0000 0111	1111 3433	4323 3332	2223 4432	3322 3332	3332 4443	3322 3332
Wa	1111 0011	0110 0011	1123 2324	4224 3333	3334 4443	2453 3443	3333 5443	3444 4443
	25	**26**	**27**	**28**	**29**	**30**		
Si	3445 4222	2321 2111	2121 2122	3354 4332	3422 2111	2213 2211		
Ch	3343 2334	3311 1122	3222 1223	3452 3333	4422 1111	2211 1012		
Tu	3443 2223	2321 2122	3221 1114	3353 3244	3422 1121	2212 1012		
SJ	2322 2222	2200 1121	2111 2213	2343 2322	2410 0011	1100 0001		
Ho	2233 2111	0111 1011	2111 1112	2342 3211	1311 1010	1112 0001		
Hu	2322 3332	2200 2221	2112 2222	2332 4432	2310 1111	1101 2100		
Wa	3234 2423	1111 3122	2122 2313	2343 4252	3332 1021	1112 2211		

¨Interpolated.

Table 3--Weighted average of reduced three-hour-range indices, April to June 1943

Day	April 1943									May 1943									June 1943								
	Values K_A								Sum	Values K_A								Sum	Values K_A								Sum
1	3	3	2^x	3	2	2^x	2	2	20	4	4^x	5^x	5	3^x	3^x	4	4	34	1^x	1^x	2	2	1^x	1^x	2^x	2^x	15
2	3	2^x	3^x	1	2^x	2^x	1^x	3^x	20	4^x	3	4	4	3	3^x	2	2	26	1^x	1	1^x	3	2^x	1	1^x	1	13
3	5	4	4	4	2^x	4	2^x	3^x	29^x	3	1	1	1^x	2	2^x	2	3^x	16^x	1^x	0^x	2	1	1	1^x	1	1^x	10
4	3^x	3	3	2^x	3^x	3	2^x	2^x	23^x	2	3	2^x	1^x	1^x	1^x	2^x	2^x	17	1^x	1^x	1^x	1^x	1^x	1	0^x	0^x	9^x
5	4^x	2^x	2^x	3	2^x	4^x	2^x	3^x	25^x	2	1^x	2^x	2^x	2^x	2	2	1^x	16^x	1^x	1	1	1	2	2	2	1^x	12
6	3	2	3	4^x	4	3^x	2^x	3	25^x	2^x	1^x	0^x	2	2	2	1	1^x	13	3	3^x	3^x	2^x	2	1^x	1	1^x	18^x
7	3^x	3^x	3	2^x	3^x	2	2^x	2^x	23	2^x	2	1^x	1^x	1	1	1	1^x	12	1	1	1^x	3	2^x	2^x	2	2^x	16
8	2^x	2	3	2^x	1^x	1	1	1	14^x	1	0^x	0	0^x	1	1	1	1	6	3	4	3^x	4^x	4	3^x	3	3^x	29
9	1	1	0	0^x	1^x	1	2	1^x	8^x	1	1^x	1^x	1	1	1	1	1	9	3	4	3^x	4^x	3	2^x	3	2	25^x
10	1	3	4	4	4	2^x	3	3^x	25	1	0^x	1^x	2	2	2^x	2	1	12^x	1^x	3	3^x	4^x	2	3^x	2	3	23
11	3^x	4^x	5	4	2^x	2	2^x	2	26	1^x	2	1^x	1	1^x	3	2^x	2^x	15^x	1^x	1	2	3^x	3	3	2	2^x	18^x
12	1^x	1	1^x	1^x	1^x	1	1	0^x	9^x	2^x	3^x	3^x	1^x	1	1	2	2	17	1^x	3	3^x	3	2^x	2	3	2	20^x
13	0^x	1	2	0^x	0^x	1^x	0^x	1	7^x	2^x	2	4	3	3	3	2	2	21^x	4^x	3	2^x	2^x	3	2^x	3	2^x	23^x
14	0^x	1	1	0^x	1	1	1	1	7	3^x	2^x	2	3	2	1^x	2	2^x	19	3	3	2^x	3	2	2	1^x	1	18
15	1	1	2	2^x	2^x	2^x	3	3^x	18	5^x	4^x	4	3^x	2^x	1^x	2	3	26^x	1	2	1^x	1	0^x	0^x	1	1	8^x
16	2^x	3	3^x	3^x	3	2	2^x	2	22	1	1	2	3^x	3^x	3	3^x	2^x	20	1	1	0^x	1	0^x	1	0^x	1	6^x
17	1^x	1^x	3	2	2	2	1^x	2	15^x	2^x	2^x	3^x	3	2^x	3^x	3^x	3^x	24^x	1^x	1^x	0^x	0^x	0^x	0^x	0^x	0^x	6
18	1	3^x	2	1^x	1^x	1^x	1	1^x	13^x	5	4^x	4^x	4	3^x	2^x	3	3^x	30^x	0	0^x	1	0^x	0^x	0^x	1	1	5
19	2	2	0^x	1	2	1	1^x	0^x	10^x	3^x	3^x	4	2^x	3	2	3^x	2^x	24^x	1^x	1	1^x	2^x	2^x	3	2^x	4	18^x
20	0	1^x	1^x	2^x	3	3	1^x	3	16	2^x	1	1	2	2	1	1^x	1^x	12^x	4	3^x	2	3^x	2^x	2^x	2^x	3	23^x
21	3^x	3^x	3	4	3^x	3	3	2	25^x	1	1	2	2^x	1^x	1^x	1	0^x	11	3^x	2^x	2^x	4	3	3	3	3	24^x
22	1^x	2^x	3	3	1	1^x	1	1	14^x	1	1	1^x	1	1	1	0^x	1^x	8^x	2^x	4	4^x	2^x	2^x	3	3	2	24
23	0^x	1	1	1^x	0^x	1	0^x	1	7	1	2	2^x	3^x	2	2	2	2^x	17^x	3	3	3	2^x	4	3^x	3^x	3	25^x
24	1	1	0^x	0^x	1	0^x	0^x	1^x	6^x	4^x	3	2^x	2^x	3	3^x	3^x	3	25^x	3^x	4	4	3^x	3	3	3^x	2^x	27
25	2^x	2^x	3	1^x	1^x	3	3	3^x	20^x	3^x	2^x	4	3	3^x	3	2^x	2^x	24^x	2^x	2^x	3	3	2^x	2^x	2	2^x	20^x
26	5^x	4^x	5	3^x	3	2^x	2	2^x	28^x	2^x	2	1^x	2	1^x	2	2^x	2^x	16^x	2	2	1	1	1^x	1	1^x	1^x	11^x
27	3	1^x	1^x	0	2	2	1	0^x	11^x	3	3	3	1^x	1	2	2^x	3	19	2^x	1	1^x	1^x	1^x	2	1^x	2^x	14
28	1	2	1^x	0	0^x	1^x	3	4	13^x	4	3^x	3^x	3^x	2^x	3	3	3	26	2^x	3	4	2^x	3^x	3	3^x	2	24
29	3	2	3	3	2	2	2	2^x	19^x	2^x	3^x	3	3	2	1^x	2^x	1	19	3	3	2	1^x	1	0^x	1^x	1	13^x
30	3	4	3	4^x	2^x	2^x	2^x	3	25	2^x	2	3^x	1^x	1^x	1^x	2	1^x	16	1^x	1^x	1	2	1	1	0^x	1	9^x
31										1^x	1^x	2	2	1^x	2	1^x	2	14									

Survey at Cheltenham (Maryland), Honolulu (Hawaii), San Juan (Puerto Rico), Sitka (Alaska), and Tucson (Arizona)." This character-figure is being designated C_A, and its values for the first twelve, the second twelve, and all twenty-four hours of each Greenwich day for April to June, 1943, are given in Table 1.

The three-hour-range indices, K, have been compiled since April 6, 1940, for each of the seven American-operated observatories. The eight indices for each day give geomagnetic activity for three-hour periods successively during the Greenwich day. The indices range from "zero" very quiet to "nine" extremely disturbed. The K-indices for Sitka (Si), Cheltenham (Ch), Tucson (Tu), San Juan (SJ), Honolulu (Ho), Huancayo (Hu), and Watheroo (Wa), for April to June, 1943, are given in Table 2. Interpolated indices are shown thus, $\ddot{3}$.

In the manner set forth in the Journal for September, 1940, the indices are standardized into reduced indices K_r to eliminate local variations. A weighted mean index K_A, is derived from the reduced indices. The reduced indices from Si, Ch, and Wa are given double weight and those from Tu, SJ, Ho, and Hu are given single weight. The weighted indices, K_A, for April to June, 1943, are given in Table 3. A superior cross ($^\times$) following an index-number denotes a half-unit, thus $5^\times = 5.5$, etc.

Department of Terrestrial Magnetism,
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Washington, D. C., July 28, 1943

DER MAGNETISCHE CHARAKTER DES JAHRES 1941*

Von J. Bartels

Die Zahl der Observatorien, deren Charakterschätzungen teils unmittelbar, teils durch Vermittlung des Chefs des Sekretariats der Internationalen Meteorologischen Organisation (Dr. Swoboda) verwendet werden konnten, war in Januar und Februar 58, im März 57, im April bis Juni 39, im Juli bis Oktober 33, im Oktober bis Dezember 38. Die stärkste Abnahme dieser Zahl tritt Ende März ein, durch den Ausfall der Meldungen von 16 russischen Observatorien. Wie im Vorjahre[1] wurden die Internationalen Charakterzahlen C einfach als Durchschnitt aller verfügbaren Charakterschätzungen abgeleitet. Zwar hätte sich die Unstetigkeit zu Anfang April 1941 dadurch vermeiden lassen, dass man die russischen Schätzungen auch schon für das erste Vierteljahr 1941 ausgelassen hätte; dadurch würde die Unstetigkeit aber nur auf Anfang Januar 1941 vorverlegt, was für den Zweck von C kein Vorteil wäre.

Immerhin schien es ratsam zu prüfen, ob die Homogenität der Reihe der C durch den gleichzeitigen Ausfall so vieler Observatorien so stark gelitten hat, dass eine nachträgliche Homogenisierung durch Angleichung der Häufigkeitsverteilungen notwendig geworden wäre; ein Verfahren dafür hatte sich bei der Bestimmung von C für die Jahre 1884 bis 1889 bewährt.[2]

Aus dem einfachen Vergleich der Monatsmittel ergibt sich bereits, dass die russischen Schätzungen durchschnittlich um ein bis zwei Zehntel unter dem Niveau der übrigen Observatorien liegen. Im Durchschnitt aller Observatorien macht es aber höchstens ein halbes Zehntel aus, ob die russischen Schätzungen einbezogen werden oder nicht.

Einen genaueren Einblick gewährt der Vergleich der Häufigkeitsverteilungen; in der letzten Tabelle ist das Material so geordnet, dass die Spalten gruppen von links nach rechts auseinander folgen. Der Rangvergleich hat folgende Bedeutung: Man denkt sich in den Reihen a, b, c, die je 90 Werte umfassen, alle Werte vom kleinsten bis zum grössten nach der Grösse geordnet; dadurch erhält jeder Wert eine Rangziffer ρ. Aus den Gesamthäufigkeiten (Anzahl $\leqq C$) lässt sich für jede Rangziffer ρ der Wert von C ohne weiteres ablesen; die drei letzten Spalten der Tabelle enthalten diese Werte C für ausgewählte Rangziffern ρ. Man ersieht durch Vergleich der Spalten a und b, dass der Fortfall der russischen Stationen für die Aktivitätsgrade $C = 0.0$ bis $C = 1.0$ gelegentlich eine Erhöhung um 0.1 bewirkt, dass aber für die höheren Stufen der Ausfall der Observatorien nichts ausmacht. Der Unterschied der C-Werte gleichen Ranges in den Spalten a und b stellt vermutlich auch die Wirkung des Fortfalls der russischen Observatorien beim Uebergang von März auf April 1941 dar. Man hätte also die Reihe der C für die letzten drei Vierteljahre 1941 dadurch an das 1. Vierteljahr anschliessen können, dass man gewisse Werte der C zwischen 0.0 und 1.0 um ein Zehntel herabsetzte, je nach der Abrundung bei der Division der Charaktersummen durch die Zahl der Observatorien. Diese Korrektur erschien aber so geringfügig, dass es unnötig schien, diese "Assimilation der Häufigkeitsverteilungen" wirklich durchzuführen.

Im ganzen ergibt sich, dass die Qualität und Homogenität von C auch für das Jahr 1941 nicht wesentlich hinter den früheren Jahren zurücksteht.

*Reprinted from Met. Zs., **60**, 28-30 (1943).

[1]Met. Zs., **58**, 339 (1941).

[2]J. Bartels. Trans. Washington Meeting 1939, Internat. Union Geod. Geophys., Ass. Terr. Mag. Elec., Bull. Nr. 11, 183-195 (1940).

Charakterzahlen 1941

Tag	Jan.	Feb.	März	Apr.	Mai	Juni	Juli	Aug.	Sep.	Okt.	Nov.	Dez.
1	1.1	0.3	2.0	0.4	0.7	0.4	0.5	0.5	1.0	0.3	1.7	1.7
2	0.4	0.4	1.4	0.7	0.3	0.1	0.4	1.4	0.6	0.5	0.4	1.1
3	0.3	1.1	1.2	0.8	0.3	0.2	0.8	0.9	0.3	0.3	0.5	0.8
4	0.4	0.6	1.4	0.3	0.9	0.1	1.3	1.8	0.1	0.2	0.2	1.0
5	0.2	1.0	1.3	0.4	0.3	0.1	2.0	1.3	0.0	0.4	0.9	0.9
6	1.0	1.1	1.0	0.6	0.5	0.6	1.5	1.2	0.0	0.2	1.4	0.6
7	0.9	1.2	1.0	1.1	0.3	0.3	1.5	1.1	1.2	0.1	0.9	0.4
8	0.4	1.0	0.8	0.8	0.6	0.4	0.9	0.2	0.7	0.7	0.9	0.6
9	0.8	0.7	0.8	0.9	0.6	0.9	1.0	0.1	0.7	0.3	0.8	0.6
10	0.6	0.4	0.3	1.2	0.6	1.4	1.2	0.1	0.4	0.7	1.1	0.3
11	0.6	0.3	0.7	1.1	0.3	1.3	0.5	0.4	0.5	1.6	1.1	0.1
12	0.4	0.3	0.6	0.8	0.4	0.7	0.5	0.4	0.2	0.9	0.7	0.2
13	0.3	1.4	0.9	0.4	0.6	1.5	0.2	0.5	1.3	0.5	0.3	0.9
14	0.1	1.1	1.8	0.1	0.4	1.2	0.2	0.3	1.2	0.9	0.3	1.1
15	0.2	1.1	1.0	0.5	0.4	1.2	0.2	0.2	1.3	0.8	0.2	0.8
16	0.8	0.7	0.3	0.7	0.9	0.2	0.9	0.1	1.0	0.9	0.4	0.9
17	1.6	1.1	0.1	0.3	1.2	1.1	0.6	0.1	0.6	0.2	1.4	0.8
18	1.4	0.3	0.5	1.0	0.6	1.1	0.3	0.3	2.0	0.3	1.2	0.9
19	1.2	0.4	1.2	1.4	0.3	0.6	0.3	1.1	2.0	0.7	1.0	0.2
20	0.8	0.8	1.3	0.7	0.2	1.1	0.5	0.2	1.4	0.3	0.5	0.2
21	0.4	1.4	1.4	0.4	1.3	0.8	1.4	0.5	1.3	0.2	0.6	0.3
22	0.6	1.5	1.3	0.2	1.2	0.7	1.1	0.2	0.2	1.6	0.9	0.3
23	1.3	1.4	1.0	0.1	1.2	0.3	0.9	0.1	1.0	0.9	0.9	0.8
24	1.4	1.1	0.6	1.7	1.2	0.5	0.7	0.4	1.2	0.9	0.3	0.5
25	1.3	1.0	0.3	1.3	1.0	0.4	0.8	0.8	1.1	0.5	0.4	0.1
26	1.1	0.6	0.1	0.9	0.6	0.7	0.1	1.3	0.2	0.8	0.1	0.5
27	1.1	0.2	0.1	0.2	0.4	0.8	0.0	1.6	0.5	0.4	0.8	0.9
28	0.7	0.5	1.7	1.1	0.6	0.4	0.2	1.3	0.5	0.3	1.6	0.4
29	0.3		1.5	0.9	0.6	0.6	0.1	1.3	0.9	0.4	0.6	0.7
30	0.7		1.9	0.2	0.6	0.3	0.2	1.2	0.8	0.4	0.4	0.4
31	0.1		1.6		0.7		0.4	0.6		1.6		0.3
Mittel	0.73	0.82	1.00	0.71	0.64	0.67	0.68	0.69	0.81	0.61	0.75	0.62

Jahresmittel: 0.73

Monat	Ruhige Tage						Gestörte Tage				
Jan.	(0.20)	5	14	15	21	31	17 (1.6)	18 (1.4)	23 (1.3)	24 (1.4)	25 (1.3)
Feb.	(0.28)	1	11	12	18	27	7 (1.2)	13 (1.4)	21 (1.4)	22 (1.5)	23 (1.4)
März	(0.18)	10	16	17	26	27	1 (2.0)	14 (1.8)	28 (1.7)	30 (1.9)	31 (1.6)
Apr.	(0.16)	14	22	23	27	30	7 (1.1)	10 (1.2)	19 (1.4)	24 (1.7)	25 (1.3)
Mai	(0.28)	2	3	5	19	20	17 (1.2)	21 (1.3)	22 (1.2)	23 (1.2)	24 (1.2)
Juni	(0.14)	2	3	4	5	16	10 (1.4)	11 (1.3)	13 (1.5)	14 (1.2)	15 (1.2)
Juli	(0.12)	13	14	26	27	29	4 (1.3)	5 (2.0)	6 (1.5)	7 (1.5)	21 (1.4)
Aug.	(0.10)	9	10	16	17	23	2 (1.4)	4 (1.8)	26 (1.3)	27 (1.6)	29 (1.3)
Sep.	(0.10)	4	5	6	12	22	13 (1.3)	15 (1.3)	18 (2.0)	19 (2.0)	20 (1.4)
Okt.	(0.18)	4	6	7	17	21	11 (1.6)	12 (0.9)	16 (0.9)	22 (1.6)	31 (1.6)
Nov.	(0.24)	4	15	16	24	26	1 (1.7)	6 (1.4)	10 (1.1)	17 (1.4)	28 (1.6)
Dez.	(0.18)	11	12	20	21	25	1 (1.7)	2 (1.1)	14 (1.1)	16 (0.9)	27 (0.9)

Zur Vervielfältigung vorgeschlagene Tage:

**März 1; Juli 5; September 18 und 19.

*März 30 und 31; April 24; August 4 und 5; Oktober 31; November 1; Dezember 1.

1941	Anzahl der Observatorien			Monatsmittel der Charakterzahlen		
	Jan.	Feb.	März	Jan.	Feb.	März
(*a*) Alle Observatorien	58	58	57	0.73	0.82	1.00
(*b*) Nichtrussische Observatorien allein	42	42	41	0.75	0.88	1.05
(*c*) Russische Observatorien allein	16	16	16	0.65	0.68	0.88

Häufigkeiten verschieden berechneter Charakterzahlen C, und Rangvergleich Januar bis März 1941

[(*a*) = Alle Observatorien; (*b*) = Nichtrussische Observatorien allein; (*c*) = Russische Observatorien allein]

C	Häufigkeiten							Rangvergleich		
	Einzel			Gesamt ≦ *C*			Rang			
	a	*b*	*c*	*a*	*b*	*c*	*ρ*	*a*	*b*	*c*
0.0	0	0	9	0	0	9	1	0.1	0.1	0.0
0.1	5	3	7	5	3	16	5	0.1	0.2	0.0
0.2	3	3	10	8	6	26	10	0.3	0.4	0.1
0.3	10	3	2	18	9	28	15	0.3	0.4	0.1
0.4	8	10	7	26	19	35	20	0.4	0.5	0.2
0.5	2	7	4	28	26	39	25	0.4	0.5	0.2
0.6	7	4	4	35	30	43	30	0.6	0.6	0.4
0.7	5	7	1	40	37	44	35	0.6	0.7	0.4
0.8	6	3	9	46	40	53	40	0.7	0.8	0.6
0.9	2	6	7	48	46	60	45	0.8	0.9	0.8
1.0	8	16	2	56	52	62	50	1.0	1.0	0.8
1.1	9	0	6	65	62	68	55	1.0	1.1	0.9
1.2	4	6	3	69	68	71	60	1.1	1.1	0.9
1.3	5	6	5	74	74	76	65	1.1	1.2	1.1
1.4	8	7	4	82	81	80	70	1.3	1.3	1.2
1.5	2	3	2	84	84	82	75	1.4	1.4	1.3
1.6	2	2	3	86	86	85	80	1.4	1.4	1.4
1.7	1	2	0	87	88	85	85	1.6	1.6	1.6
1.8	1	1	3	88	89	88	88	1.8	1.7	1.8
1.9	1	0	0	89	89	88	90	2.0	2.0	2.0
2.0	1	1	2	90	90	90				

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(See also page 186)

PROVISIONAL SUNSPOT-NUMBERS FOR FEBRUARY AND MARCH, 1943

(Dependent alone on observation at Zürich Observatory)

Day	February	March
1	10	46
2	11*	38
3	20	16
4	16	10[d]
5	7	16
6	0	19
7	..	37
8	*E*25[cc]	32
9	38	39
10	37	39[b]
11	37[b]*	53
12	31	46
13	21	44
14	29	21
15	16	29
16	16	11
17	11	0
18	*E*15[c]	10[d]
19	11	11
20	20[d]	21
21	*E*31[c]	*E*37[c]
22	*M*54[c]	25
23	62	35
24	60	34[a]
25	63[b]	28[a]
26	61	25
27	50	24
28	56	20
29		10?*
30		*M*25[c]
31		33[d]
Means......	29.9	26.9
No. days....	27	31

Mean for quarter January to March, 1943, 23.0 (87 days)

*Observed at Locarno.
[a]Passage of an average-sized group through the central meridian.
[b]Passage of a large group or spot through the central meridian.
[c]New formation of a group developing into a middle-sized or large center of activity: *E*, on the eastern part of the Sun's disk; *W*, on the western part; *M*, in the central-circle zone.
[d]Entrance of a large or average-sized center of activity on the east limb.

EIDGEN. STERNWARTE,
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W. BRUNNER

LIST OF GEOMAGNETIC OBSERVATORIES AND THESAURUS OF VALUES*—II

By J. A. Fleming and W. E. Scott

Table 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Valencia[1] Cahirciveen	+51 56	349 45	1900	−21 30.0	+68 29.6	17765	16529	−6511	+45084	48458
			1901	−21 27.7	+68 26.3	17801	16567	−6513	+45048	48438
			1902[s]	−21 24.2	+68 23.9	17833	16603	−6508	+45037	48439
			1903[s]	−21 18.7	+68 22.4	17833	16614	−6481	+44980	48387
			1904	−21 15.2	+68 20.9	17840	16627	−6467	+44939	48352
			1905	−21 10.4	+68 19.2	17848	16643	−6447	+44896	48313
			1906	−21 06.3	+68 16.9	17867	16669	−6434	+44856	48283
			1907	−21 01.4	+68 17.0	17870	16680	−6411	+44866	48295
			1908	−20 55.7	+68 16.3	17871	16692	−6385	+44843	48273
			1909	−20 50.3	+68 15.1	17877	16708	−6359	+44812	48246
			1910	−20 44.6	+68 13.0	17892	16732	−6337	+44771	48215
			1911	−20 38.1	+68 12.1	17889	16741	−6304	+44730	48174
			1912	−20 29.3	+68 10.3	17898	16766	−6265	+44684	48134
			1913	−20 19.6	+68 09.2	17892	16778	−6215	+44628	48081
			1914	−20 12.3	+68 07.8	17895	16794	−6181	+44585	48042
			1915	−20 03.8	+68 07.9[t]	17869	16785	−6130	+44519[t]	47972
			1916	−19 53.1	+68 06.6	17869	16804	−6078	+44473	47929
			1917	−19 43.0	+68 06.9	17855	16808	−6024	+44448	47900
			1918	−19 36.2	+68 06.5	17844	16810	−5987	+44407	47858
			1919	−19 27.2	+68 06.1	17842	16823	−5942	+44385	47837
			1920	−19 17.9	+68 05.3	17840	16838	−5896	+44353	47806
			1921	−19 06.5	+68 03.4	17848	16865	−5842	+44299	47760
			1922	−18 57.0	+68 03.0	17849	16882	−5796	+44289	47750
			1923	−18 46.5	+68 01.5	17852	16902	−5746	+44242	47707
			1924	−18 34.9	+68 00.6	17854	16923	−5689	+44213	47682
			1925	−18 22.4	+68 00.0	17849	16939	−5626	+44177	47646
			1926	−18 10.8	+68 00.1	17835	16945	−5565	+44147	47612
			1927	−17 59.5	+67 59.2	17837	16965	−5509	+44119	47588
			1928	−17 48.0	+67 59.3	17826	16973	−5449	+44096	47563
			1929	−17 37.3	+67 59.6	17821	16985	−5395	+44094	47559
			1930	−17 27.6	+67 59.8	17813	16992	−5345	+44081	47546
			1931	−17 16.8	+67 58.7	17815	17011	−5292	+44048	47514
			1932	−17 05.4	+67 58.5	17809	17023	−5234	+44024	47490
			1933	−16 54.5	+67 57.9	17811	17041	−5180	+44005	47473
			1934	−16 43.7	+67 57.5	17812	17058	−5127	+43993	47461
			1935	−16 32.7	+67 57.4	17804	17067	−5070	+43969	47437
			1936	−16 21.6	+67 57.7	17801	17080	−5014	+43972	47438
			1937	−16 11.7	+67 58.0	17802	17096	−4965	+43987	47453
Clausthal	+51 48	10 20	1890	−12 14.6	....	.....	.....	......	....	.....
			1891	−12 06.9	....	.....	.....	......	....	.....
			1892	−12 00.0	....	.....	.....	......	....	.....
			1893	−11 50.5	....	.....	.....	......	....	.....
			1894	−11 41.2	....	.....	.....	......	....	.....
			1895	−11 34.0	....	.....	.....	......	....	.....
			1896	−11 25.8	....	.....	.....	......	....	.....
			1897	−11 19.7	....	.....	.....	......	....	.....
			1898	−11 14.7	....	.....	.....	......	....	.....
			1899	−11 07.8	....	.....	.....	......	....	.....
			1900	−11 01.9	....	.....	.....	......	....	.....
			1901[u]	[−10 55.2]	....	.....	.....	......	....	.....
			1902	−10 48.5	....	.....	.....	......	....	.....
			1903	−10 47.0	....	.....	.....	......	....	.....
			1904	−10 43.2	....	.....	.....	......	....	.....
			1905	−10 40.3	....	.....	.....	......	....	.....
			1906	−10 33.0	....	.....	.....	......	....	.....
			1907	−10 29.3	....	.....	.....	......	....	.....
			1908	−10 25.1	....	.....	.....	......	....	.....
			1909	−10 18.9	....	.....	.....	......	....	.....
			1910	−10 07.6	....	.....	.....	......	....	.....
			1911	−10 00.7	....	.....	.....	......	....	.....
			1912	− 9 54.0	....	.....	.....	......	....	.....
			1913	− 9 44.5	....	.....	.....	......	....	.....
			1914	− 9 36.1	....	.....	.....	......	....	.....
			1915	− 9 29.8	....	.....	.....	......	....	.....
			1916	− 9 14.6	....	.....	.....	......	....	.....
			1917	− 9 06.9	....	.....	.....	......	....	.....
			1918	− 9 01.6	....	.....	.....	......	....	.....

[s]Because of change in hour of observation from June 1903, *H* is reduced as compared with previous years, approximately 4γ with consequent reduction in *Z* of approximately 10γ.
[t]No observations in May 1915. [u]Repairs to variometer in 1901.

*Continued from pp 97-108, Terr. Mag., 48, 1943, which see for numbered footnotes.

Table 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, + =N − =S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Nijnedevitzsk	+51 31	38 22	1935	+ 5 33.6	+67 34.7	18588	18501	+1801	+45060	48743
Bochum	+51 29	7 14	1900	−12 47.2	....	.....	.....	......	....	.....
			1901	−12 42.8	....	.....	.....	......	....	.....
			1902	−12 39.4	....	.....	.....	......	....	.....
			1903	−12 35.7	....	.....	.....	......	....	.....
			1904	−12 31.4	....	.....	.....	......	....	.....
			1905	−12 27.2	....	.....	.....	......	....	.....
			1906	−12 22.5	....	.....	.....	......	....	.....
			1907	−12 17.4	....	.....	.....	......	....	.....
			1908	−12 11.2	....	.....	.....	......	....	.....
			1909	−12 04.1	....	.....	.....	......	....	.....
			1910	−11 56.4	....	.....	.....	......	....	.....
			1911	−11 48.3	....	.....	.....	......	....	.....
			1912	−11 39.4	....	.....	.....	......	....	.....
			1913	−11 30.6[v]	....	.....	.....	......	....	.....
			1914	−11 19.2[v]	....	.....	.....	......	....	.....
			1915	−11 08.9[v]	....	.....	.....	......	....	.....
			1916	−10 59.3[v]	....	.....	.....	......	....	.....
			1917	−10 49.7[v]	....	.....	.....	......	....	.....
			1918	−10 40.4[v]	....	.....	.....	......	....	.....
			1919	−10 31.4[v]	....	.....	.....	......	....	.....
			1920	−10 19.9[w]	....	.....	.....	......	....	.....
			1921	−10 10.4[w]	....	.....	.....	......	....	.....
			1922	− 9 58.8	....	.....	.....	......	....	.....
			1923	− 9 46.8	....	.....	.....	......	....	.....
			1924	− 9 36.6	....	.....	.....	......	....	.....
			1925	− 9 25.9	....	.....	.....	......	....	.....
			1926	− 9 19.7	....	.....	.....	......	....	
			1927	− 9 08.5[x]	....	.....	.....	......	....	.....
			1928	− 8 57.4[x]	....	.....	.....	......	....	.....
			1929	− 8 46.0[x]	....	.....	.....	......	....	.....
			1930	− 8 35.2[x]	....	.....	.....	......	....	.....
			1931	− 8 23.8[x]	....	.....	.....	......	....	.....
			1932	− 8 13.7[x]	....	.....	.....	......	....	.....
			1933	− 8 02.8[x]	....	.....	.....	......	....	.....
			1934	− 7 52.4[x]	....	.....	.....	......	....	.....
Kew	+51 28	359 41	1900	−16 52.7	+67 11.8	18422	17628	−5349	+43818	47532
			1901	−16 48.9	+67 09.5	18445	17656	−5336	+43790	47516
			1902	−16 44.8	+67 08.0	18469	17686	−5322	+43795	47528
			1903	−16 40.5	+67 06.5	18482	17705	−5303	+43770	47513
			1904	−16 37.9	+67 05.1	18498	17724	−5294	+43759	47508
			1905	−16 32.9	+67 03.8	18504	17738	−5270	+43727	47481
			1906	−16 28.5	+67 02.2	18514	17754	−5251	+43694	47455
			1907	−16 23.1	+67 01.6	18511	17759	−5222	+43666	47427
			1908	−16 16.9	+67 00.9	18509	17767	−5189	+43636	47399
			1909	−16 10.8	+66 59.7	18506	17773	−5157	+43588	47353
			1910	−16 03.2	+66 58.7	18503	17781	−5117	+43546	47313
			1911	−15 55.3	+66 57.2	18502	17792	−5076	+43490	47262
			1912	−15 46.5	+66 56.5	18498	17801	−5029	+43454	47227
			1913	−15 37.0	+66 55.8	18505	17822	−4982	+43449	47226
			1914	−15 27.8	+66 55.8	18488	17819	−4929	+43406	47179
			1915	−15 18.4	+66 56.6	18463	17808	−4874	+43376	47141
			1916	−15 08.8	+66 57.5	18457	17816	−4823	+43395	47156
			1917	−14 59.6	+66 58.0	18437	17809	−4770	+43366	47122
			1918	−14 50.4	+66 58.4	18429	17814	−4720	+43361	47115
			1919	−14 40.9	+66 57.7	18416	17815	−4667	+43305	47058
			1920	−14 31.0	+66 57.9	18410	17822	−4615	+43297	47049
			1921	−14 19.9	+66 57.7	18399	17827	−4555	+43266	47016
			1922	−14 08.8	+66 57.6	18394	17836	−4495	+43251	47000
			1923	−13 57.3	+66 57.0	18394	17851	−4436	+43230	46980
			1924	−13 45.1	+66 56.5	18392	17865	−4372	+43205	46957
Greenwich[y]	+51 28	0 00	1840	....	....	.....	.....	......	....	.....
			1841	−23 16.2	....	.....	.....	......	....	.....
			1842	−23 14.6	....	.....	.....	......	....	.....
			1843	−23 11.7	+69 00.6	.....	.....	......	....	.....
			1844	−23 15.3	+69 00.3	.....	.....	......	....	.....
			1845	−22 56.7	+68 57.5	.....	.....	......	....	.....
			1846	−22 49.6	+68 58.1	17310	15950	−6720	+45020	48230
			1847	−22 51.3	+68 59.0	17360	16000	−6740	+45190	48410
			1848	−22 51.8	+68 54.7	17310	15950	−6730	+44890	48110
			1849	−22 37.8	+68 51.3	17330	16000	−6670	+44810	48040

[v]Means of values at 08^h and 14^h daily. [w]Means all hourly scalings. [x]Absolute values only. [y]The values of *H*, *X*, *Y*, *Z*, and *F* are given to the nearest 10γ. Results of observations June 1818 to December 1820 of declination with a Dolland magnet thrice daily (generally at 08^h, 12^h, and 16^h) were: 1818, −24° 19′; 1819, −24° 21′; 1820, −24° 21′.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, + = N − = S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Greenwich[y]—Continued...	+51 28	0 00	1850	−22 23.5	+68 46.9	17380	16070	−6620	+44770	48030
			1851	−22 18.3	+68 40.4	17440	16140	−6620	+44670	47950
			1852	−22 17.9	+68 42.7	17450	16150	−6620	+44780	48060
			1853	−22 10.1	+68 44.6	17480	16190	−6600	+44930	48210
			1854	−22 00.8	+68 47.7	17490	16210	−6560	+45080	48350
			1855	−21 48.4	+68 44.6	17560	16300	−6520	+45140	48440
			1856	−21 43.5	+68 43.5	17590	16340	−6510	+45170	48470
			1857	−21 35.4	+68 31.1	17690	16450	−6510	+44950	48310
			1858	−21 30.3	+68 28.3	17620	16390	−6460	+44670	48020
			1859	−21 23.5	+68 26.9	17610	16400	−6420	+44590	47940
			1860	−21 14.3	+68 30.1	.....	.....	......	....	.....
			1861[z]	....	+68 24.6	17730	16540	−6380	+44800	48180
			1861[z]	−21 05.5	+68 15.8	17590	16410	−6330	+44120	47500
			1862	−20 52.6	+68 09.6	17630	16470	−6280	+44030	47430
			1863	−20 45.9	+68 07.0	17640	16490	−6250	+43960	47370
			1864[z]	−[20 39.9]	+68 04.1	17670	[16530]	[−6240]	+43930	47350
			1865	−20 33.9	+68 02.7	17670	16540	−6210	+43880	47300
			1866	−20 28.0	+68 01.3	17730	16610	−6200	+43970	47410
			1867	−20 20.5	+67 57.2	17770	16660	−6180	+43920	47380
			1868	−20 13.1	+67 56.5	17790	16690	−6150	+43950	47410
			1869	−20 04.1	+67 54.8	17820	16740	−6110	+43960	47430
			1870	−19 53.0	+67 52.5	17840	16780	−6070	+43920	47400
			1871	−19 41.9	+67 50.3	17860	16810	−6020	+43890	47380
			1872	−19 36.8	+67 47.8	17890	16850	−6010	+43830	47340
			1873	−19 33.4	+67 45.8	17930	16900	−6000	+43860	47380
			1874	−19 28.9	+67 43.6	17970	16940	−5990	+43870	47410
			1875	−19 21.2	+67 42.4	17970	16950	−5960	+43830	47370
			1876	−19 08.3	+67 41.0	17990	17000	−5900	+43830	47380
			1877	−18 57.2	+67 39.7	18000	17020	−5850	+43810	47360
			1878	−18 49.3	+67 38.2	18020	17060	−5810	+43820	47380
			1879	−18 40.5	+67 37.0	18050	17100	−5780	+43820	47390
			1880	−18 32.6	+67 35.7	18050	17110	−5740	+43800	47370
			1881	−18 27.1	+67 34.7	18070	17140	−5720	+43790	47370
			1882	−18 22.3	+67 34.2	18060	17140	−5690	+43750	47330
			1883	−18 15.0	+67 31.7	18120	17210	−5670	+43810	47410
			1884	−18 07.6	+67 29.7	18140	17240	−5640	+43790	47400
			1885	−18 01.7	+67 28.0	18170	17280	−5620	+43800	47420
			1886	−17 54.5	+67 27.1	18180	17300	−5590	+43770	47400
			1887	−17 49.1	+67 26.6	18190	17320	−5570	+43800	47430
			1888	−17 40.4	+67 25.6	18220	17360	−5530	+43830	47470
			1889	−17 34.9	+67 24.3	18230	17380	−5510	+43800	47440
			1890	−17 28.6	+67 23.0	18250	17410	−5480	+43810	47460
			1891	−17 23.4	+67 21.5	18270	17430	−5460	+43800	47460
			1892	−17 17.4	+67 20.0	18290	17460	−5440	+43790	47460
			1893	−17 11.4	+67 17.9	18310	17490	−5410	+43730	47410
			1894	−17 04.6	+67 17.4	18310	17500	−5380	+43740	47420
			1895	−16 57.4	+67 16.1[a]	18340	17540	−5350	+43780	47470
			1896	−16 51.7[a]	+67 15.1[a]	18350[a]	17560	−5320	+43820	47510
			1897	−16 45.8[a]	+67 13.5[a]	18380	17600	−5300	+43770	47470
			1898	−16 39.2[a]	+67 12.1	18400	17630	−5270	+43770	47480
			1899	−16 34.2	+67 10.5	18430	17660	−5260	+43800	47520
			1900	−16 29.0	+67 08.8	18460	17700	−5240	+43800	47530
			1901	−16 26.0	+67 06.4	18500	17740	−5230	+43810	47560
			1902	−16 22.8	+67 03.8	18520	17770	−5220	+43770	47530
			1903	−16 19.1	+67 01.2	18520	17770	−5200	+43680	47440
			1904	−16 15.0	+66 57.6	18540	17800	−5190	+43590	47370
			1905	−16 09.9	+66.56 3	18540	17810	−5160	+43550	47330
			1906	−16 03.6	+66 55.6	18540	17820	−5130	+43530	47310
			1907	−15 59.8	+66 56.2	18550	17830	−5110	+43570	47350
			1908	−15 53.5	+66 56.3	18540	17830	−5080	+43560	47340
			1909	−15 47.6	+66 54.1	18540	17840	−5050	+43480	47270
			1910	−15 41.2	+66 52.8	18550	17860	−5020	+43450	47240
			1911	−15 33.0	+66 52.1	18550	17870	−4970	+43420	47220
			1912	−15 24.3	+66 51.8	18550	17880	−4930	+43400	47200
			1913	−15 15.2	+66 50.5	18530	17880	−4880	+43330	47130
			1914[z]	−15 06.3	+66.50 8	18530	17890	−4830	+43330	47130
			1915	−14 56.5	+66 51.6	18510	17880	−4770	+43310	47100
			1916	−14 46.9	+66 52.2	18480	17870	−4710	+43260	47040
			1917	−14 37.1	+66 53.0	18480	17880	−4660	+43300[b]	47080
			1918	−14 27.8	+66 52.8	18460	17870	−4610	+43250	47020
			1919	−14 18.2	+66 53.3	18450	17880	−4560	+43240	47010

[z]In 1861 the Kew new unifilar apparatus for *H* and the Airy dip-circle for *I* were introduced, both sets of apparatus being used in that year; old *H*-determinations require to be diminished by 1/117 part to make comparable with those of the Kew unifilar; to October 6, 1861, observations of *I* were made with the instrument by Robinson used in preceding years and from October 22, 1861, with the Airy dip-circle; in 1864 the excavation of the Magnetic Basement caused suspension of complete *D*-observations; in 1914 the dip-circle was replaced by an earth-inductor and thereafter values of *I* were deduced from annual mean values of *H* and *Z* instead of, as previously, from *H* and *I*. [a]Corrected for effects of iron in new buildings. [b]Mean 10 months, March to December, 1917.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, + =N − =S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Greenwich[y]—Continued...	+51 28	0 00	1920	−14 08.6	+66 53.6	18450	17890	−4510	+43250	47020
			1921	−13 57.6	+66 53.0	18450	17910	−4450	+43220	46990
			1922	−13 46.7	+66 52.3	18440	17910	−4390	+43180	46950
			1923	−13 35.1	+66 51.9	18430	17910	−4330	+43140	46910
			1924	−13 22.8	+66 51.6	18430	17930	−4260	+43110	46880
			1925[c]	−13 09.9	+66 51.4	18410	17930	−4190	+43080	46850
Abinger (Succeeding Greenwich)...........	+51 11	359 37	1925[d]	−13 22.7	+66 35.1	18597	18092	−4303	+42946	46798
			1926	−13 10.4	+66 36.3	18581	18092	−4234	+42947	46796
			1927	−12 58.4	+66 36.2	18575	18100	−4170	+42932	46777
			1928	−12 47.0	+66 37.3	18564	18104	−4107	+42941	46784
			1929	−12 35.8	+66 37.2	18555	18108	−4047	+42918	46757
			1930	−12 24.6	+66 38.2	18542	18109	−3985	+42924	46758
			1931	−12 13.7	+66 38.1	18543	18122	−3928	+42923	46757
			1932	−12 02.6	+66 39.1	18536	18128	−3868	+42940	46770
			1933	−11 51.7	+66 39.4	18532	18136	−3809	+42942	46770
			1934	−11 41.1	+66 39.7	18533	18149	−3754	+42955	46783
			1935	−11 30.3	+66 40.9	18527	18155	−3695	+42981	46804
			1936	−11 20.0	+66 41.8	18524	18163	−3640	+43007	46827
			1937	−11 10.4	+66 42.7	18522	18171	−3589	+43031	46848
			1938	−11 01.4	+66 43.2	18522	18180	−3542	+43050	46865
			1939	−10 51.9	+66 43.5	18528	18196	−3492	+43074	46890
			1940	−10 43.0	+66 43.9	18533	18210	−3446	+43099	46915
			1941	−10 33.8	+66 44.3	18539	18225	−3399	+43128	46944
Uccle Brussels...............	+50 48	4 21	1900	−14 13.6	+66 09.8	18952	18371	−4658	+42896	46896
			1901	−14 08.3	+66 07.8	18956	18382	−4630	+42838	46844
			1902	−14 03.1	+66 07.0	18998	18430	−4613	+42905	46923
			1903	−14 00.6	+66 05.5	19044	18477	−4610	+42958	46990
			1904	−13 57.7	+66 04.8	19075	18511	−4602	+43006	47045
			1905	−13 53.7	+66 03.8	19069	18511	−4579	+42956	47000
			1906	−13 49.0	+66 02.9	19080	18528	−4557	+42952	46999
			1907	−13 42.9	+66 02.3	19048	18505	−4516	+42859	46902
			1908	−13 36.7	+66 01.6	19061	18526	−4486	+42867	46912
			1909	−13 29.7	+66 00.9	19030	18505	−4441	+42772	46815
			1910	−13 22.2	+66 00.8	19028	18512	−4400	+42764	46807
			1911	−13 13.9	+66 00.1	19025	18520	−4355	+42734	46778
			1912	−13 05.9	+66 00.5	19027	18532	−4312	+42752	46795
			1913	−12 56.8	+66 00.3	19021	18537	−4262	+42732	46774
			1914	−12 48.0	+66 00.7	19007	18535	−4211	+42714	46752
			1915	−12 38.3	+66 01.2[e]	18989	18529	−4155	+42690[e]	46723
			1916	−12 28.6	+66 02.4	18973	18525	−4099	+42694	46720
			1917	−12 19.2	+66 02.7	18964	18527	−4046	+42684	46707
			1918	−12 10.0	+66 02.6	.....	.....	.....	.....	.....
			1919	−12 00.6	+66 02.9	.....	.....	.....	.....	.....
			1920	−11 50.6	+66 04.1	.....	.....	.....	.....	.....
			1921	−11 39.0	+66 03.7	.....	.....	.....	.....	.....
			1922	−11 28.2	+66.03.5	.....	.....	.....	.....	.....
			1923	−11 15.1	....	.....	.....	.....	.....	.....
			1924	−11 03.8	....	.....	.....	.....	.....	.....
			1925	−10 52.7	....	.....	.....	.....	.....	.....
			1926	−10 39.7	....	.....	.....	.....	.....	.....
			1927	−10 26.9	....	.....	.....	.....	.....	.....
			1928	−10 16.0	....	.....	.....	.....	.....	.....
			1929	−10 05.4	....	19234	.....	.....	.....	.....
			1930	− 9 54.6	....	.....	.....	.....	.....	.....
			1931	− 9 46	....	.....	.....	.....	.....	.....
			1932	− 9 36	....	.....	.....	.....	.....	.....
			1933	− 9 28.9	....	.....	.....	.....	.....	.....
			1934	− 9 18.3	....	.....	.....	.....	.....	.....
Hermsdorf	+50 46	16 14	1901	− 8 13.6	....	.....	.....	.....	.....	.....
			1902	− 8 08.9	....	.....	.....	.....	.....	.....
			1903	− 8 04.0	....	.....	.....	.....	.....	.....
			1904	− 7 59.3	....	.....	.....	.....	.....	.....
			1905	− 7 55.0	....	.....	.....	.....	.....	.....
			1906	− 7 49.8	....	.....	.....	.....	.....	.....
			1907	− 7 44.2	....	.....	.....	.....	.....	.....
			1908	− 7 39.0	....	.....	.....	.....	.....	.....
			1909	− 7 31.9	....	.....	.....	.....	.....	.....
			1910	− 7 23.9	....	.....	.....	.....	.....	.....
			1911	− 7 15.5	....	.....	.....	.....	.....	.....
			1912	− 7 06 9	....	.....	.....	.....	.....	.....

[c]Electrified section of Southern Railway, which passes near Observatory, was opened June 6, 1926, and absolute observations were then discontinued. [d]Mean of 10 months, February to November, 1925. [e]For 10 months, January to October, 1915.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, D	Inclination, I	Components of intensity				
						Horizontal, H	North, X	East, Y	Vertical, Z	Total, F
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Hermsdorf—Continued....	+50 46	16 14	1913	− 6 58.2	....	.....	.....	......	....	.....
			1914	− 6 48.0	....	.....	.....	......	....	.....
			1915	− 6 37.8	....	.....	.....	......	....	.....
			1916	− 6 26.2	....	.....	.....	......	....	.....
			1917	− 6 19.7	....	.....	.....	......	....	.....
			1918	− 6 07.6	....	.....	.....	......	....	.....
			1919	− 6 01.8	....	.....	.....	......	....	.....
			1920	− 5 53.1	....	.....	.....	......	....	.....
			1921	− 5 42.8	....	.....	.....	......	....	.....
			1922	− 5 32.1	....	.....	.....	......	....	.....
			1923	− 5 19.2	....	.....	.....	......	....	.....
			1924	− 5 04.9	....	.....	.....	......	....	.....
			1925	− 4 54.3	....	.....	.....	......	....	.....
			1926	− 4 39.6	....	.....	.....	......	....	.....
			1927	− 4 29.3	....	.....	.....	......	....	.....
			1928	− 4 19.6	....	.....	.....	......	....	.....
			1929	− 4 10.6	....	.....	.....	......	....	.....
Beuthen...............	+50 21	18 55	1900	− 6 53.7	....	.....	.....	......	....	.....
			1901	− 6 49.1	....	.....	.....	......	....	.....
			1902	− 6 44.3	....	.....	.....	......	....	.....
			1903	− 6 39.0	....	.....	.....	......	....	.....
			1904	− 6 33.7	....	.....	.....	......	....	.....
			1905	− 6 27.9	....	.....	.....	......	....	.....
			1906	− 6 23.0	....	.....	.....	......	....	.....
			1907	− 6 17.9	....	.....	.....	......	....	.....
			1908	− 6 12.3	....	.....	.....	......	....	.....
Beuthen-Mikilow.........	+50 09	18 54	1925	− 3 37.8	....	.....	.....	......	....	.....
			1926	− 3 26.7	....	.....	.....	......	....	.....
			1927	− 3 16.0	....	.....	.....	......	....	.....
			1928	− 3 06.2	....	.....	.....	......	....	.....
			1929	− 2 56.6	....	.....	.....	......	....	.....
			1930	− 2 46.1	....	.....	.....	......	....	.....
			1931	− 2 36.8	....	.....	.....	......	....	.....
			1932	− 2 28.0	....	.....	.....	......	....	.....
Falmouth[f].............	+50 09	354 55	1900	−18 29.1	+66 45.2	18689	17725	−5925	+43507	47351
			1901	−18 25.5	+66 42.8	18720	17760	−5917	+43495	47353
			1902	−18 21.5	+66 40.4	18737	17783	−5901	+43451	47319
			1903	−18 18.3	+66 37.6	18759	17810	−5892	+43405	47285
			1904	−18 12.0	+66 37.8	18759	17821	−5859	+43414	47292
			1905	−18 08.4	+66 36.1	18749	17817	−5837	+43328	47212
			1906	−18 05.3	+66 33.7	18790	17861	−5834	+43342	47239
			1907	−18 00.4	+66 32.7	18799	17878	−5811	+43328	47230
			1908	−17 54.7	+66 31.4	18798	17887	−5781	+43281	47187
			1909	−17 48.4	+66 30.6	18802	17901	−5750	+43262	47171
			1910	−17 41.6	+66 29.1	18802	17913	−5714	+43211	47124
			1911	−17 33.0	+66 28.2	18798	17923	−5668	+43171	47086
			1912	−17 24.2	+66 26.6	18799	17938	−5623	+43118	47038
Prague.................	+50 05	14 25	1900	− 9 07.0	....	.....	.....	......	....	.....
			1901	− 9 01.7	....	.....	.....	......	....	.....
			1902	− 8 57.6	....	19903	19660	−3100	....	.....
			1903	− 8 53.6	....	19885	19646	−3074	....	.....
			1904	− 8 48.7	....	20023	19787	−3067	....	.....
			1905	− 8 43.3	....	.....	.....	......	....	.....
			1906	− 8 38.2	....	.....	.....	......	....	.....
			1907	− 8 31.4	....	.....	.....	......	....	.....
			1908	− 8 20.9	....	.....	.....	......	....	.....
			1909	− 8 15.1	....	.....	.....	......	....	.....
			1910	− 8 09.6	....	.....	.....	......	....	.....
			1911	− 7 59.3	....	.....	.....	......	....	.....
			1912	− 7 50.3	....	.....	.....	......	....	.....
			1913	− 7 42.2	....	.....	.....	......	....	.....
			1914	− 7 32.1	....	.....	.....	......	....	.....
			1915	− 7 24.2	....	.....	.....	......	....	.....
			1916	− 7 14.3	....	.....	.....	......	....	.....
			1917	− 7 05.4	....	.....	.....	......	....	.....
			1918	− 6 54.3	....	.....	.....	......	....	.....
			1919	− 6 46.2	....	.....	.....	......	....	.....
			1920	− 6 35.6	....	.....	.....	......	....	.....
			1921	− 6 26.0	....	.....	.....	......	....	.....
			1922	− 6 14.1	....	.....	.....	......	....	.....

[f]Prior to 1903 the I-values are the means of absolute observations; beginning with 1903 they are the means of the five quiet days for each month; Observatory was discontinued June 30, 1913.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, + = N − = S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity				
						Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Prague—Continued	+50 05	14 25	1923	− 6 02.4	....	.....	.....	......	....	.....
			1924	− 5 51.0[g]	....	.....	.....	......	....	.....
			1925	− 5 39.9	....	.....	.....	......	....	.....
			1926	− 5 27.7	....	.....	.....	......	....	.....
Cracow	+50 04	19 58	1907	− 5 47.9	....	.....	.....	......	....	..
			1908	− 5 44.6	....	.....	.....	......	....	.....
			1909	− 5 35.1	+64 18	.....	.....	......	....	.....
			1910	− 5 27.4	....	.....	.....	......	....	.....
			1911	− 5 18.1	+64 15.5	.....	.....	......	....	.....
			1912	− 5 13.4	+64 10.7	.....	.....	......	....	.....
			1913	− 5 03.3	+64 18.4	.....	.....	......	....	.....
Janów	+49 54	23 44	1933	+ 0 06.4[h]	+64 50.9[i]	20110[j]	20110[i]	+ 37[i]	+42830[k]	47316
			1934	+ 0 12.7	+64 53.9[i]	20081	20081[i]	+ 74[i]	+42863	47334
St. Helier (Jersey)[l]	+49 12	357 55	1902	−16 54.1	+65 40.3	.....	.....	......	....	.....
			1903	−16 50.4	+65 39.2	.....	.....	......	....	.....
			1904	−16 45.0	+65 37.3	.....	.....	......	....	.....
			1905	−16 39.3	+65 36.1	.....	.....	......	....	.....
			1906	−16 31.7	+65 35.0	.....	.....	......	....	.....
			1907	−16 27.4	+65 34.5	.....	.....	......	....	.....
Val Joyeux (Succeeding Parc St. Maur)	+48 49	2 01	1901	−15 12.0	+64 58.9	19680	18991	−5160	+42167	46534
			1902	−15 08.6	+64 56.6	19700	19016	−5146	+42139	46517
			1903	−15 04.4	+64 54.7	19711	19033	−5126	+42102	46488
			1904	−15 00.0	+64 52.4	19721	19049	−5104	+42048	46443
			1905	−14 55.7	+64 50.7	19728	19062	−5082	+42008	46410
			1906	−14 51.3	+64 47.9	19740	19080	−5061	+41945	46357
			1907	−14 45.9	+64 46.5	19740	19088	−5031	+41900	46317
			1908	−14 39.6	+64 44.6	19735	19092	−4995	+44831	46252
			1909	−14 32.9	+64 43.9	19727	19095	−4995	+41792	46214
			1910	−14 25.7	+64 43.0	19738	19116	−4918	+41789	46216
			1911	−14 17.6	+64 41.6	19744	19133	−4874	+41758	46191
			1912	−14 08.9	+64 40.1	19747	19148	−4827	+41714	46152
			1913	−13 59.2	+64 38.9	19744	19159	−4772	+41673	46114
			1914	−13 49.8	+64 38.4	19733	19161	−4717	+41631	46071
			1915	−13 40.5	+64 38.8	19715	19156	−4661	+41607	46042
			1916	−13 30.3	+64 40.3	19700	19155	−4603	+41623	46050
			1917	−13 21.5	+64 41.2	19689	19157	−4549	+41629	46050
			1918	−13 12.4	+64 43.2	19680	19159	−4496	+41669	46083
			1919	−13 02.9	+64 43.1	19668	19160	−4440	+41643	46054
			1920	−12 53.0	+64 41.6	19666	19171	−4385	+41591	46006
			1921	−12 42.6	+64 40.0	19670	19188	−4328	+41548	45969
			1922	−12 31.5	+64 39.6	19661	19193	−4264	+41517	45937
			1923	−12 20.2	+64 39.0	19664	19210	−4202	+41504	45926
			1924	−12 07.9	+64 38.9	19663	19224	−4132	+41501	45923
			1925	−11 55.8	+64 38.7	19659	19235	−4064	+41485	45908
			1926	−11 43.8	+64 39.2	19650	19239	−3995	+41482	45900
			1927	−11 32.3	+64 39.8	19656	19259	−3932	+41514	45932
			1928	−11 20.4	+64 39.9	19648	19265	−3864	+41502	45918
			1929	−11 10.1	+64 41.0	19641	19269	−3804	+41519	45931
			1930	−10 59.3	+64 42.0	19631	19271	−3742	+41529	45936
			1931	−10 49.0	+64 43.4	19636	19288	−3685	+41584	45987
			1932	−10 38.0	+64 43.7	19637	19299	−3623	+41596	45998
			1933	−10 27.4	+64 44.2	19639	19313	−3565	+41615	46016
			1934	−10 17.5	+64 44.3	19643	19327	−3509	+41629	46031
			1935	−10 06.7	+64 45.4	19642	19337	−3448	+41658	46057
			1936	− 9 56.7	+64 45.4	19647	19351	−3393	+41668	46067
Vienna Auhof	+48 12	16 14	1929	− 4 12.4	+63 24.4	20519	20464	−1505	+40988	45837
			1930	− 4 02.6	+63 26.8	20511	20460	−1447	+41042	45882
			1931	− 3 53.8	+63 29.0	20506	20458	−1394	+41099	45931
			1932	− 3 44.5	+63 30.8	20507	20463	−1338	+41153	45979
			1933	− 3 35.1	+63 32.7	20507	20467	−1283	+41213	46033
			1934	− 3 25.8	+63 34.4	20501	20465	−1227	+41254	46067
			1935	− 3 16.7	+63 38.1	20486	20452	−1171	+41332	46130
			1936	− 3 07.3	+63 40.7	20475	20445	−1115	+41387	46174
			1937	− 2 59.0	+63 41.8	20472	20444	−1065	+41444	46225
Maisach	+48 12	11 15	1927	− 6 52.5	+63 32.5	20314	20168	−2432	+40813	45593
			1928	− 6 41.6	+63 35.2	20298	20160	−2366	+40866	45629
			1929	− 6 29.9	+63 35.8	20292	20162	−2297	+40872	45632

[g]No observations during August and September, 1924. [h]Seven months, May to December, 1933. [i]Not homogeneous. [j]Four months, September to December, 1933. [k]Three months, October to December, 1933. [l]Discontinued in 1915 "because of the present and future difficulties entailed by the present state of war."

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Maisach—Continued.....	+48 12	11 15	1930	− 6 20.2	+63 39.7	20279	20155	−2238	+40963	45708
			1931	− 6 12.2	+63 41.1	20288	20169	−2192	+41022	45765
			1932	− 5 59.3	+63 39.8	20299	20188	−2118	+41005	45754
Munich................	+48 09	11 37	1899	−10 33.7	+63 21.5	20583	20234	−3773	+41029	45902
			1900	−10 27.9	+63 18.5	20610	20267	−3743	+40993	45883
			1901	−10 23.2	+63 17.7	20631	20293	−3720	+41011	45908
			1902	−10 19.2	+63 12.8	20648	20314	−3699	+40901	45816
			1903	−10 14.4	+63 11.1	20654	20325	−3672	+40864	45787
			1904	−10 09.1	+63 10.8	20654	20331	−3640	+40855	45779
			1905	−10 04.3	+63 10.2	20651	20333	−3611	+40828	45754
			1906	− 9 59.5	+63 10.0	20655	20342	−3584	+40830	45758
			1907	− 9 53.7	+63 09.6	20644	20337	−3548	+40797	45722
			1908	− 9 47.3	+63 08.1	20636	20336	−3508	+40739	45667
			1909	− 9 39.9	+63 06.6	20631	20338	−3464	+40684	45615
			1910	− 9 31.5	+63 08.4	20638	20353	−3415	+40750	45678
			1911	− 9 23.7	+63 06.2	20634	20357	−3368	+40678	45612
			1912	− 9 15.2	+63 05.6	20631	20363	−3317	+40654	45589
			1913	− 9 06.2	+63 04.6	20623	20363	−3263	+40609	45546
			1914	− 8 58.3	....	.....	.....	......	....	.....
			1915	− 8 49.3	....	.....	.....	......	....	.....
			1916	− 8 40.0	....	.....	.....	......	....	.....
			1917	− 8 32.0	....	.....	.....	......	....	.....
			1918	− 8 23.2	....	.....	.....	......	....	.....
			1919	− 8 13.7	....	.....	.....	......	....	.....
			1920	− 8 03.8	....	.....	.....	......	....	.....
			1921	− 7 53.6	....	.....	.....	......	....	.....
			1922	[− 7 41.5]	....	.....	.....	......	....	.....
			1923	− 7 29.1	....	.....	.....	......	....	.....
			1924	− 7 17.5	....	.....	.....	......	....	.....
			1925	− 7 06.7	....	.....	.....	......	....	.....
			1926	− 6 54.7	....	.....	.....	......	....	.....
Kremsmünster[l]..........	+48 03	14 08	1900	− 9 18.7	....	.....	.....	......	....	.....
			1901	− 9 16.8	....	.....	.....	......	....	.....
			1902	− 9 11.7	....	.....	.....	......	....	.....
			1903	− 9 06.7	....	.....	.....	......	....	.....
			1904	− 9 02.4	....	.....	.....	......	....	.....
Chambon-la-Forêt[ll] (Succeeding Val Joyeux)	+48 01	2 16	1936	− 9 28.9	+64 11.3	20011	19737	−3296	+41374	45959
			1937	− 9 19.1	+64 12.9	20011	19747	−3240	+41422	46002
O'Gyalla (Pesth)...............	+47 53	18 12	1900	− 7 28.8	....	.....	.....	......	....	.....
			1901	− 7 23.3	....	21175	20999	−2723	....	.....
			1902	− 7 18.5	....	21170	20998	−2693	....	.....
			1903	− 7 14.0	+62 27.3	21178	21009	−2667	+40605	45796
			1904	− 7 08.7	+62 27.9[m]	21144[m]	20980[m]	−2630[m]	+40557[m]	45738[m]
			1905	− 7 03.0	....	21151	20991	−2596	....	.....
			1906	− 6 57.8	....	.....	.....	......	....	.....
			1907	− 6 55.4	....	21142	20988	−2548	....	.....
			1908	− 6 49.7	+62 28.8	21127	20977	−2512	+40550	45724
			1909	− 6 44.0	+62 29.8	21094	20949	−2473	+40515	45677
			1910	− 6 34.5	+62 31.2	21082	20943	−2414	+40533	45688
			1911	− 6 25.3	....	21067	20935	−2356	+40492	45645
			1912	− 6 17.3	....	21060	20933	−2307	....	.....
			1913[n]	− 6 08.4	....	.....	.....	......	....	.....
			1914	− 5 59.0	....	.....	.....	......	....	.....
			1915	− 5 49.3	....	20995	20887	−2130	....	.....
			1916	− 5 40.2	....	20962	20859	−2071	....	.....
			1917	− 5 30.3	....	20941	20844	−2009	....	.....
			1918	− 5 21.1	....	20917	20826	−1951	....	.....
O'Gyalla v (Sťará Dala)..........	+47 52	18 11	1924	− 4 18.6	....	.....	.....	......	....	.....
			1925	− 4 08.9	....	.....	.....	......	....	.....
			1926	− 3 57.2	....	.....	.....	......	....	.....
			1927	− 3 47.0	....	.....	.....	......	....	.....
			1928	− 3 36.7	....	.....	.....	......	....	.....
			1929	− 3 27.4	....	.....	.....	......	....	.....
			1930	− 3 18.8	....	.....	.....	......	....	.....
			1931	− 3 10.3	....	.....	.....	......	....	.....
			1932	− 3 00.9	....	.....	.....	......	....	.....
			1933	− 2 51.3	....	.....	.....	......	....	.....

[ll] Initiated January 1, 1936, to take place of Val Joyeux because of electric-car disturbances at latter; (Val Joyeux—Chambon) = +27′.9 in *D*, +33′.6 in *I*, −365γ in *H*, and +278γ in *Z*. [m] For year 1904 *I*, *H*, *X*, *Y*, and *Z* are from means for January through September; there seems a slight discontinuity in *H* because of the introduction of a new magnetometer. [n] No vertical-intensity results in 1913 because of rebuilding of instrument.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, + =N − =S	Longitude, east	Year	Declination, D	Inclination, I	Components of intensity				
						Horizontal, H	North, X	East, Y	Vertical, Z	Total, F
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
O'Gyalla [v] (Stará Dala)—Continued	+47 52	18 11	1934	− 2 42.5	....	.....	.....	......	....	.....
			1935	− 2 32.7	....	.....	.....	......	....	.....
			1936	− 2 22.6	....	.....	.....	......	....	.....
			1937	(− 2 16.8)	....	.....	.....	......	....	.....
Nantes[o]	+47 15	358 26	1923	−13 23.5	+63 45.8	20212	19662	−4681	+41009	45720
			1924	−13 11.6	+63 41.6	20240	19706	−4620	+40940	45670
			1925	−12 59.6	+63 39.0	20234	19716	−4549	+40850	45586
			1926	−12 48.2	+63 40.3	20227	19724	−4482	+40876	45607
			1927	−12 35.6	+63 41.0	20237	19750	−4412	+40917	45648
			1928	−12 23.6	+63 41.2	20220	19749	−4338	+40886	45613
			1929	−12 13.5	+63 43.1	20222	19763	−4282	+40950	45671
			1930	−12 04.6	+63 43.3	20226	19778	−4232	+40965	45686
			1931	−11 54.6	+63 43.3	20241	19805	−4177	+40995	45720
			1932	−11 43.8	+63 44.4	20244	19821	−4118	+41035	45757
			1933	−11 33.4	+63 44.4	20250	19840	−4056	+41045	45768
			1934	−11 22.9	+63 43.1	20245	19847	−3995	+40995	45721
			1935	−11 13.5	+63 42.9	20245	19858	−3941	+40989	45717
			1936	−11 03.4	+63 42.9	20251	19875	−3884	+41004	45732
			1937	−10 53.4	+63 43.2	20250	19885	−3826	+41008	45735
Toyohara	+46 58	142 45	1932	− 8 55.3[p]	+60 41.1[p]	25034[p]	24732[q]	−3883[q]	+44584[p]	51131[p]
			1933	− 8 56.8	+60 41.3	25035	24731	−3893	+44591	51138
			1934	....	....	.....	.....	......	....	.....
			1935	− 9 03.5	+60 42.3	25029	24717	−3941	+44609	51152
			1936	(− 9 06.6)	(+60 42.1)	(25029)	(24713)	(−3963)	(+44625)	(51165)
			1937	(− 9 09.9)	(+60 42.7)	(25029)	(24709)	(−3987)	(+44618)	(51158)
			1938	(− 9 12.9)	(+60 42.1)	(25035)	(24712)	(−4009)	(+44615)	(51159)
Otomari[1]	+46 39	142 46	1920	− 8 11.3	....	.....	.....	......	....	.....
			1921	− 8 15.4	....	.....	.....	......	....	.....
			1922	− 8 18.7	....	.....	.....	......	....	.....
			1923	− 8 20.6	....	.....	.....	......	....	.....
			1924	− 8 23.5	....	.....	.....	......	....	.....
			1925	− 8 25.9	....	.....	.....	......	....	.....
			1926	− 8 29.1	....	.....	.....	......	....	.....
			1927	− 8 30.8	....	.....	.....	......	....	.....
			1928	− 8 32.6	....	.....	.....	......	....	.....
			1929	− 8 35.0	....	.....	.....	......	....	.....
			1930	− 8 35.5	....	.....	.....	......	....	.....
			1931	− 8 36.2	....	.....	.....	......	....	.....
			1932	− 8 38.5	....	.....	.....	......	....	.....
			1933	− 8 40.8	....	.....	.....	......	....	.....
			1934	− 8 43.9	....	.....	.....	......	....	.....
			1935	− 8 46.8	....	.....	.....	......	....	.....
			1936	− 8 49.9	....	.....	.....	......	....	.....
			1937	(− 8 51.8)	....	.....	.....	......	....	.....
			1938	(− 8 55.5)	....	.....	.....	......	....	.....
Odessa[2]	+46 26	30 46	1896[r]	− 4 49.6	+62 33.9	22038	21960	−1854	+42452	47831
			1897	− 4 47.3	+62 30.9[s]	22039	21962	−1840	+42372	47761
			1898	− 4 41.5	+62 30.5	22033	21959	−1802	+42341	47731
			1899	− 4 36.7	+62 18.9	21869	21798	−1758	+41660[t]	47051
			1900[u]	− 4 29.9	+62 18.0	21876	21809	−1716	+41659	47053
			1901	− 4 27.0	....	.....	.....	......	....	.....
			1908[v]	− 3 53.5	+62 22.1	21758	21708	−1477	+41563	46914
			1909[w]	− 3 41.0	+62 26.4	21709	21664	−1395	+41595	46919
			1910	− 3 35.9	+62 26.9	21707	21664	−1362	+41606	46928
			1922	− 2 01.3	+63 09.0	.....	.....	......	....	.....
			1923	− 1 52.9	+63 11.9	21267	21256	− 698	+42098	47165
			1924	− 1 44.6	+63 15.1	21246	21236	− 645	+42154	47205
			1925	− 1 36.4	+63 18.9	21213	21205	− 595	+42206	47237
Pola	+44 52	13 51	1900	− 9 25.8	+60 15.9	22192	21892	−3636	+38852	44743
			1901	− 9 20.7	+60 13.2	22220	21925	−3608	+38829	44738
			1902	− 9 15.7	+60 10.6	22224	21934	−3577	+38769	44687
			1903	− 9 10.7	+60 09.9	22225	21940	−3545	+38753	44673
			1904	− 9 06.0	+60 07.9	22231	21951	−3516	+38709	44640
			1905	− 9 00.1	+60 07.6	22227	21953	−3478	+38695	44625
			1906	− 8 54.4	+60 06.0	22225	21957	−3441	+38652	44585

[o] Electrical disturbance, especially in Z. [p] Five months, August to December, 1932. [q] Four months, September to December, 1932. [r] Four months, September to December, 1896. [s] Six months, April to September, 1897; for nine months, January to September, 1897, mean values were: $I = +62° 31'.9$; $Z = 42384\gamma$; $F = 47771\gamma$. [t] No values in June and July 1899. [u] Ten months, January to October, 1900. [v] Absolute values January, February, March, May, June, November, and December, 1908. [w] Two months, November and December, 1909.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity				
						Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Pola—Continued	+44 52	13 51	1907	− 8 49.3	+60 07.0	22214	21951	−3407	+38656	44585
			1908	− 8 43.2	+60 06.8	22208	21951	−3367	+38640	44567
			1909	− 8 36.2	+60 06.1	22194	21944	−3320	+38599	44525
			1910	− 8 28.0	+60 04.7	22194	21952	−3268	+38562	44493
			1911	− 8 17.5	+60 03.6	22190	21958	−3200	+38526	44459
			1912	− 8 08.5	+60 03.6	22199	21975	−3144	+38544	44480
			1913	− 7 58.1	+60 03.6	22200	21986	−3077	+38544	44481
			1914	− 7 48.3	+60 03.5	22190	21984	−3013	+38524	44457
			1915	− 7 39.0	+60 05.1	22166	21969	−2951	+38526	44447
			1916	− 7 28.3	+60 05.6	22144	21956	−2901	+38499	44413
			1917	− 7 19.2	+60 06.8	22124	21944	−2819	+38494	44400
			1918	− 7 11.0	+60 09.0	22113	21939	−2765	+38533	44427
			1919[x]	− 7 01.6	+60 09.3	22111	21945	−2705	+38539	44431
			1921[y]	− 6 38.6	+60 10.3	22094	21946	−2556	+38534	44418
			1922	− 6 28.0	+60 12.8	22090	21949	−2488	+38591	44467
Agincourt	+43 47	280 44	1899	− 5 27.7	+74 34.8	16491	16416	−1570	+59789	62021
			1900	− 5 28.8	+74 31.6	16497	16422	−1575	+59594	61835
			1901	− 5 30.5	+74 31.2	16490	16414	−1583	+59542	61783
			1902	− 5 32.6	+74 31.1	16472	16395	−1591	+59470	61709
			1903	− 5 35.0	+74 31.7	16460	16382	−1601	+59467	61703
			1904	− 5 39.3	+74 32.3	16429	16349	−1619	+59395	61626
			1905	− 5 43.1	+74 33.4	16411	16329	−1635	+59404	61629
			1906	− 5 46.2	+74 34.1	16387	16304	−1647	+59365	61585
			1907	− 5 51.5	+74 35.7	16357	16272	−1670	+59364	61576
			1908	− 5 55.0	+74 36.5	16322	16235	−1682	+59290	61496
			1909	− 6 00.3	+74 37.5	16277	16188	−1703	+59194	61391
			1910	− 6 04.8	+74 38.6	16248	16157	−1721	+59163	61353
			1911	− 6 09.9	+74 39.1	16212	16118	−1741	+59065	61250
			1912	− 6 14.6	+74 39.7	16184	16088	−1760	+59004	61183
			1913	− 6 19.3	+74 40.6	16137	16039	−1777	+58893	61064
			1914	− 6 24.7	+74 41.3	16092	15991	−1797	+58775	60939
			1915	− 6 29.4	+74 42.7	16034	15931	−1812	+58657	60809
			1916	− 6 33.4	+74 43.5	15987	15882	−1826	+58538	60682
			1917	− 6 36.2	+74 44.2	15950	15844	−1834	+58449	60587
			1918	− 6 38.3	+74 44.8	15916	15809	−1840	+58366	60496
			1919	− 6 41.0	+74 44.9	15885	15777	−1849	+58260	60386
			1920	− 6 45.4	+74 44.6	15865	15755	−1867	+58166	60291
			1921	− 6 50.6	+74 44.5	15839	15726	−1887	+58065	60185
			1922	− 6 56.2	+74 44.6	15809	15694	−1910	+57961	60078
			1923	− 7 00.9	+74 44.3	15784	15666	−1928	+57849	59963
			1924	− 7 05.8	+74 44.3	15752	15631	−1946	+57733	59843
			1925	− 7 09.7	+74 44.2	15727	15604	−1961	+57628	59736
			1926	− 7 13.4	+74 44.6	15692	15569	−1973	+57529	59630
			1927	− 7 16.4	+74 44.3	15664	15540	−1983	+57412	59508
			1928	− 7 20.3	+74 44.9	15628	15500	−1996	+57315	59407
			1929	− 7 24.0	+74 45.4	15586	15456	−2007	+57197	59282
			1930	− 7 28.1	+74 46.4	15544	15412	−2020	+57103	59181
			1931	− 7 31.9	+74 46.3	15520	15386	−2034	+57010	59086
			1932	− 7 35.8	+74 46.9	15485	15349	−2047	+56924	58991
			1933	− 7 37.7	+74 47.4	15453	15316	−2051	+56837	58900
			1934	(− 7 37.8)	(+74 47.9)	(15423)	(15286)	(−2048)	(+56762)	(58820)
			1935	(− 7 37.4)	(+74 48.9)	(15391)	(15255)	(−2042)	(+56708)	(58760)
			1936	(− 7 36.8)	(+74 49.8)	(15362)	(15227)	(−2035)	(+56657)	(58703)
			1937	(− 7 35.9)	(+74 50.6)	(15333)	(15198)	(−2027)	(+56604)	(58644)
Nice[1]	+43 43	7 16	1900	−12 01.9	+60 07.9	22397	21905	−4669	+38999	44973
			1901[z]	−11 58.0	....	.....	.....	......	....	.....
Toulouse[1]	+43 37	1 28	1900	−14 17.7[a]	+60 55.4[b]	21913[b]	21235	−5411	+39408	45091
			1901	−14 13.7	+60 56.5[c]	21963[c]	21289	−5398	+39527	45219
			1902	−14 11.2[d]	+60 53.7	21985[e]	21315	−5388	+39491	45198
			1903	−14 09.1[f]	+60 54.5[f]	21990[g]	21323	−5376	+39522	45228
			1904	−14 05.8	+60 52.5[i]	21984[h]	21322	−5354	+39457	45168
			1905	−13 59.7	+60 52.1	22013[j]	21360	−5324	+39498	45218
Perpignan	+42 42	2 53	1907	−13 04.4	....	.....	.....	......	....	.....
			1908	−12 58.5	....	.....	.....	......	....	.....
			1909	−12 52.0	....	.....	.....	......	....	.....
			1910	−12 44.8	....	.....	.....	......	....	.....

[x]No observations January, 1920, to August, 1921. [y]Four months, September to December, 1921. [z]Because of interference by electric tramway Observatory removed to Mt. Mournier. [a]June to September and November and December, 1900. [b]No observations during March and October, 1900. [c]No observations during August and September, 1901. [d]No observations during July and September, 1902. [e]No observations during July, September, and November, 1902. [f]No observations during June, July, and August, 1903. [g]No observations during September, 1903. [h]No observations during September, 1904. [i]No observations during July, 1904. [j]No observations during September, 1905.

Table 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, D	Inclination, I	Components of intensity: Horizontal, H	North, X	East, Y	Vertical, Z	Total, F
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Karsani (Succeeding Tiflis)	+41 50	44 42	1908	+ 2 39.8	+56 28.4	25404	25377	+1180	+38343	45995
			1909	+ 2 46.8	+56 32.1	25377	25347	+1231	+38391	46021
			1910	+ 2 52.7	+56 35.5	25343	25311	+1273	+38422	46028
			1911	+ 2 57.4	+56 41.2	25289	25255	+1304	+38480	46046
			1912	+ 3 03.1	+56 46.0	25255	25219	+1344	+38545	46082
			1913	+ 3 09.1	+56 51.1	25217	25179	+1386	+38612	46117
			1926	+ 4 12.3	+58 03.0	24694	24628	+1811	+39595	46664
			1927	+ 4 15.5	+58 08.1	24673	24605	+1832	+39693	46736
			1928	+ 4 18.8	+58 13.5	24646	24576	+1854	+39788	46803
			1929	+ 4 19.7	+58 19.0	24627	24557	+1859	+39901	46889
			1930	+ 4 21.7	+58 24.9	24599	24528	+1871	+40008	46966
			1931	+ 4 22.5	+58 28.5	24596	24524	+1876	+40097	47039
			1932	+ 4 23.9	+58 33.0	24581	24509	+1885	+40192	47113
			1933	+ 4 25.4	+58 37.1	24576	24503	+1895	+40291	47195
			1934	+ 4 26.5	+58 40.9	24574	24500	+1903	+40388	47276
Tiflis (Succeeded by Karsani)	+41 43	44 48	1898	+ 2 05.5	+55 50.6	25635	25618	+ 936	+37784	45659
			1899	+ 2 11.0	+55 52.1	25614	25599	+ 976	+37785	45652
			1900	+ 2 16.4	+55 53.2	25594	25574	+1015	+37783	45636
			1901	+ 2 21.3	+55 54.4	25571	25549	+1051	+37777	45618
			1902	+ 2 27.1	+55 56.2	25542	25519	+1093	+37777	45602
			1903	+ 2 32.5	+55 58.6	25505	25480	+1131	+37781	45583
			1904	+ 2 37.1	+56 00.9	25476	25449	+1164	+37792	45576
			1905	+ 2 41.6	+56 02.8	25451	25423	+1196	+37799	45569
Tashkent	+41 20	69 18	1928	+ 5 38.5	+59 48.5	25332	25209	+2490	+43538	50371
			1930[k]	+ 5 30.8	....	25276	25159	+2428	....	.....
			1931	+ 5 27.4	....	.....	.....	......	....	.....
			1932	+ 5 25.3	....	.....	.....	......	....	.....
			1933	+ 5 23.7	....	.....	.....	......	....	.....
			1934	+ 5 19.9	....	.....	.....	......	....	.....
			1935[k]	+ 5 17.2	....	.....	.....	......	....	.....
Capodimonte[1]	+40 52	14 15	1882	....	+57 00.0	.....	.....	......	....	.....
			1883	....	+56 56.6	23836	.....	......	+36625	43698
			1884	−10 31.4	+56 53.5	23841	23440	−4354	+36560	43647
			1885	−10 26.1	+56 52.3	23863	23468	−4322	+36566	43664
			1886	−10 20.9	+56 51.8	23868	23480	−4287	+36562	43663
			1887	−10 16.0	+56 52.5	23870	23488	−4254	+36582	43681
			1888	−10 11.7	+56 51.0	23877	23500	−4226	+36557	43664
			1889	−10 07.0	+56 49.1	23896	23524	−4197	+36542	43662
			1890	−10 02.3	+56 46.9	23917	23551	−4169	+36523	43658
			1891	− 9 56.4	−56 46.0	23932	23573	−4131	+36526	43668
			1892	− 9 52.1	+56 46.1	23940	23586	−4103	+36540	43684
			1893	− 9 47.0	+56 42.1	23965	23616	−4072	+36486	43652
			1894	− 9 41.7	....	23986	23643	−4039	....	.....
			1895	− 9 37.0	+56 38.0	24010	23673	−4011	+36459	43655
			1896	− 9 32.1	+56 37.1	24039	23707	−3982	+36482	43690
			1897	− 9 26.3	+56 31.4	24074	23748	−3948	+36404	43644
			1898	− 9 22.6	+56 28.9	24085	23763	−3924	+36363	43616
			1899	− 9 15.8	+56 25.0	24105	23791	−3880	+36304	43578
			1900	− 9 10.2	+56 23.8	24133	23825	−3846	+36318	43605
			1901	− 9 05.7	+56 20.6	24150	23846	−3817	+36271	43575
			1902	− 9 01.7	+56 17.2	24169	23870	−3793	+36222	43545
			1903	− 8 56.5	+56 17.6	24171	23877	−3758	+36234	43556
			1904	− 8 50.4	+56 15.5	24178	23891	−3715	+36196	43529
			1905	− 8 45.3	+56 15.0	24164	23882	−3678	+36164	43494
			1906	− 8 40.3	+56 13.5	24166	23890	−3644	+36133	43469
			1907	− 8 34.8	+56 13.1	24146	23876	−3602	+36094	43426
			1908	− 8 28.3	+56 13.0	24153	23889	−3558	+36102	43436
			1909	− 8 21.3	+56 14.4	24129	23873	−3506	+36098	43420
			1910	− 8 13.0	+56 11.9	24160	23912	−3453	+36088	43428
			1911	− 8 05.5	+56 11.7	24171	23930	−3402	+36099	43444
			1912	....	+56 12.4	24150	.....	......	+36084	43420
			1913	....	....	24125	.....	......	....	.....
			1914	....	....	24166	.....	......	....	.....
			1922	− 6 25.7	+57 02.6	23705	23556	−2654	+36563	43575
Tortosa[2] Ebro	+40 49	0 31	1905	−13 56.9	+58 07.6	23230	22545	−5600	+37359	43993
			1907	−13 42.8	+58 04.8	23274	22611	−5517	+37362	44018
			1910	−13 25.9	+57 57.3	23251	22615	−5401	+37144	43821
			1911	−13 18.6	+57 54.8	23256	22631	−5354	+37092	43780
			1912	−13 09.3	+57 51.8	23271	23660	−5296	+37042	43745
			1913	−13 00.7	+57 49.3	23288	23690	−5243	+37011	43728
			1914	−12 51.6	+57 47.5	23295	23711	−5185	+36891	43707

[k]February through December, 1930, and January through June, 1935.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
Tortosa[2]	° ′	° ′	.	° ′	° ′	γ	γ	γ	γ	γ
Ebro—Continued	+40 49	0 31	1915	−12 46.0	+57 47.1	23277	22702	−5144	+36941	43663
			1916	−12 34.7	+57 46.2	23306	22747	−5075	+36967	43700
			1917	−12 24.9	+57 44.3	23301	22756	−5010	+36914	43652
			1918	−12 16.1	+57 42.8	23298	22766	−4951	+36872	43617
			1919	−12 07.6	+57 41.1	23291	22771	−4893	+36821	43570
			1920	−11 59.3	+57 39.4	23291	22783	−4838	+36781	43535
			1921	−11 49.1	+57 37.6	23301	22807	−4772	+36754	43518
			1922	−11 39.7	+57 35.5	23314	22833	−4713	+36725	43500
			1923	−11 30.6	+57 32.7	23328	22859	−4655	+36680	43471
			1924	−11 20.2	+57 30.5	23359	22903	−4591	+36678	43485
			1925	−11 08.8	+57 28.4	23367	22927	−4518	+36642	43458
			1926	−10 59.1	+57 27.7	23362	22935	−4452	+36617	43436
			1927	−10 48.8	+57 26.5	23380	22966	−4386	+36617	43445
			1928	−10 37.7	+57 26.8	23386	22985	−4313	+36633	43462
			1929	−10 28.0	+57 25.8	23383	22994	−4249	+36605	43436
			1930	−10 20.1	+57 25.3	23401	23022	−4198	+36621	43460
			1931	−10 11.7	+57 24.1	23415	23045	−4145	+36616	43462
			1932	−10 02.0	+57 23.6	23420	23062	−4080	+36610	43460
			1933[3]	− 9 54.3	+57 23.0	23436	23087	−4031	+36622	43479
			1934[3]	− 9 45.5	+57 22.7	23456	23117	−3975	+36646	43510
			1935	− 9 37.4	+57 23.1	23460	23130	−3922	+36662	43525
Madrid	+40 25	356 20	1900	−15 42.4	+58 38.1	.....	.....	......	....	.....
			1901	−15 35.6	....	.....	.....	......	....	.....
Coimbra[1]	+40 12	351 35	1866[l]	....	+61 17.4	21735	.....	......	+39685	45244
			1867	−20 47.8[m]	+61 12.0	21775	20356	−7731	+39607	45198
			1868	−20 44.6[n]	+61 08.2	21802	20389	−7722	+39555	45166
			1869	−20 40.3[o]	+61 04.9[p]	21832[q]	20426	−7707	+39514	45144
			1870	−20 37.3[r]	+60 59.0[s]	21869[s]	20468	−7702	+39426	45086
			1871	−20 32.1[t]	+60 54.0	21918	20525	−7688	+39382	45070
			1872	−20 20.0[u]	+60 49.1	21948	20580	−7627	+39311	45023
			1873	−20 12.5[v]	+60 43.1	22012	20657	−7604	+39243	44995
			1874	−20 01.0[w]	+60 40.0	22036	20705	−7543	+39215	44982
			1875	−19 52.8[x]	+60 36.5	22065	20750	−7503	+39180	44966
			1876	−19 42.5	+60 33.4	22097	20803	−7452	+39148	44954
			1877	−19 35.7[y]	+60 32.4	22125	20844	−7420	+39166	44983
			1878	−19 26.4	+60 30.4	22168	20904	−7378	+39193	45028
			1879	−19 18.6	+60 27.4	22197	20948	−7340	+39166	45019
			1880	−19 11.4	+60 24.4	22225	20990	−7305	+39137	45007
			1881	−19 04.3	+60 23.3	22241	21020	−7267	+39133	45011
			1882	−18 57.5	+60 22.2	22251	21044	−7229	+39123	45008
			1883	−18 50.4	+60 18.6	22287	21093	−7197	+39088	44996
			1884	−18 43.6	+60 15.5	22313	21132	−7164	+39051	44997
			1885	−18 36.8	+60 12.0	22338	21170	−7130	+39003	44997
			1886	−18 30.4	+60 10.3	22353	21197	−7095	+38987	44941
			1887	−18 24.1	+60 07.4	22371	21227	−7063	+38940	44909
			1888	−18 17.5	+60 03.9	22396	21264	−7029	+38895	44882
			1889	−18 12.3	+60 00.4	22433	21310	−7008	+38866	44875
			1890	−18 07.4	+59 57.5	22459	21345	−6986	+38835	44862
			1891	−18 02.3	+59 55.4	22478	21373	−6960	+38814	44853
			1892	−17 57.4	+59 53.2	22477	21382	−6930	+38753	44800
			1893	−17 51.7	+59 50.5	22518	21433	−6907	+38752	44822
			1894	−17 47.3	+59 48.0	22547	21469	−6888	+38741	44824
			1895	−17 42.0	+59 43.6	22581	21512	−6865	+38685	44793
			1896	−17 36.8	+59 40.2	22620	21560	−6845	+38662	44793
			1897	−17 32.3	+59 36.3	22658	21605	−6828	+38628	44783
			1898	−17 28.0	+59 33.6	22691	21645	−6811	+38613	44787
			1899	−17 24.2	+59 28.9	22724	21684	−6797	+38549	44748
			1900	−17 20.1	+59 24.3	22768	21734	−6784	+38506	44734
			1901	−17 16.1	+59 19.6	22805	21777	−6770	+38449	44703
			1902	−17 12.6	+59 15.4	22841	21818	−6758	+38403	44682
			1903	−17 09.3	+59 11.9	22859	21842	−6742	+38345	44641
			1904	−17 05.4	+59 09.4	22885	21874	−6725	+38324	44637
			1905	−17 01.5	+59 06.4	22900	21896	−6705	+38273	44601
			1906	−16 56.6	+59 03.2	22924	21929	−6681	+38232	44578
			1907	−16 51.6	+59 00.7	22935	21949	−6652	+38188	44546

[l]Seven months, June to December, 1866. [m]Six months, July to December, 1867. [n]No observations during July, September, and December, 1868. [o]No observations during March, May, August, September, and December, 1869. [p]No observations during August, 1869. [q]No observations during February and August, 1869. [r]No observations during January, February, April, May, November, and December, 1870. [s]No observations during April and December, 1870. [t]No observations during January, May, June, September, and November, 1871. [u]No observations during January and October, 1872. [v]No observations during March and August, 1873. [w]No observations during February, 1874. [x]No observations during February, May, and June, 1875. [y]From 1877 values for *D* are means of observations at 08^h and 14^h, except for January through June, 1877, when observations were made daily generally between 09^h and 13^h.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, + =N − =S	Longitude, east	Year	Declination, *D*	Inclination, *I*	Components of intensity: Horizontal, *H*	North, *X*	East, *Y*	Vertical, *Z*	Total, *F*
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Coimbra[1]—Continued.....	+40 12	351 35	1908	−16 46.2	+58 57.3	22946	21970	−6628	+38120	44493
			1909	−16 40.6	+58 54.1	22959	21993	−6589	+38063	44451
			1910	−16 34.5	+58 50.1	22986	22031	−6557	+38006	44417
			1911	−16 27.4	+58 46.4	23011	22068	−6519	+37956	44386
			1912	−16 19.7	+58 42.0	23033	22104	−6476	+37883	44335
			1913	−16 12.1	+58 38.6	23046	22131	−6430	+37820	44288
			1914	−16 04.7	+58 36.4	23057	22155	−6386	+37782	44262
			1915	−15 57.5	+58 34.7	23053	22165	−6338	+37734	44219
			1916	−15 50.1	+58 32.2	23046	22171	−6289	+37662	44154
			1917	−15 42.6	+58 29.6	23059	22198	−6244	+37618	44123
			1918	−15 35.6	+58 26.7	23062	22213	−6199	+37553	44069
			1919	−15 29.4	+58 25.0	23075	22237	−6163	+37532	44058
			1920	−15 21.5	+58 22.8	23087	22263	−6115	+37498	44035
			1921	−15 13.4	+58 19.2	23110	22299	−6068	+37448	44004
			1922	−15 04.7	+58 17.0	23096	22301	−6008	+37371	43932
			1923	−14 54.2	+58 18.9	23110	22333	−5944	+37440	43998
			1924	−14 45.6	+58 14.1	23128	22365	−5892	+37353	43934
			1925	−14 38.2	+58 13.9	23143	22392	−5848	+37372	43957
			1926	−14 28.5	+58 12.4	23144	22409	−5785	+37337	43928
			1927	−14 18.8	+58 08.1	23166	22447	−5727	+37268	43882
			1928	−14 10.4	+58 02.5	23172	22467	−5674	+37142	43778
			1929	−14 00.4	+57 57.9	23177	22488	−5610	+37041	43694
			1930	−13 55.2	+57 56.4	23179	22498	−5576	+37008	43667
			1931	−13 45.5	+57 52.2	23196	22530	−5517	+36934	43614
			1932	−13 36.2	+57 43.7	23202	22551	−5457	+36742	43455
			1933	−13 28.8	+57 45.8	23235	22595	−5416	+36844	43559
			1934	−13 22.2	+57 41.2	23230	22601	−5371	+36727	43457
			1935	−13 14.3	+57 31.4	23269	22651	−5329	+36558	43335
			1936	−13 03.0	+57 26.8	23303	22703	−5255	+36503	43307
			1937	−12 56.5	+57 20.0	23308	22716	−5220	+36352	43183
Mt. Weather............	+39 04	282 07	1908[z]	− 3 39.2	... .	.....	.....	......	....	.....
Baldwin[2]...............	+38 47	264 50	1901	+ 8 21.9	+68 34.5	21931	21698	+3190	+55890	60038
			1902	+ 8 23.0	+68 37.6	21926	21692	+3197	+56081	60215
			1903	+ 8 24.8	+68 40.0	21893	21657	+3203	+56113	60233
			1904	+ 8 26.3	+68 40.6	21856	21619	+3207	+56048	60159
			1905	+ 8 27.6	+68 43.0	21821	21584	+3210	+56016	60116
			1906	+ 8 29.7	+68 44.2	21788	21549	+3219	+56048	60134
			1907	+ 8 31.4	+68 46.2	21742	21502	+3222	+56024	60095
			1908	+ 8 33.0	+68 47.8	21692	21451	+3225	+55972	60028
			1909[a]	+ 8 34.0	+68 50.2	21644	21403	+3224	+55908	59951

[z]From magnetograms during December, 1907, to June, 1908. [a]Ten months, January to October, 1909; *I* observed to end of September, 1909, but interpolated value used for October to get mean for ten months.

(*To be continued in December number*)

GEORGE WASHINGTON LITTLEHALES, 1860-1943

By H. D. Harradon

George Washington Littlehales, Hydrographic Engineer at the United States Hydrographic Office from 1900 to 1932, died suddenly at his home in Washington, D. C., August 12, 1943, at the age of 82 years.

Mr. Littlehales was born October 14, 1860, in Schuylkill County, Pennsylvania. He entered the United States Naval Academy as a midshipman in 1879 from which he was graduated in 1883 and after spending two years at sea in the North Atlantic Squadron he received the post-

1860–1943

graduate diploma and returned to civil life. In 1888 the Columbian (now George Washington) University awarded him the degree of Civil Engineering which he had earned in the course of studies there. In the summer of 1885 he joined the staff of the United States Hydrographic Office with which he was continuously associated until his retirement in 1932. He was professor of nautical science in George Washington University during 1913-1927.

In the earlier years as Chief of the Division of Chart Construction he did notable work in extending the field of usefulness of the Hydrographic Office. Later as Chief of the Research Division of the Office, his work in hydrography and related sciences won him an international reputation as an hydrographer and oceanographer.

He always took a keen interest in the subject of terrestrial magnetism. He collaborated with Dr. Louis A. Bauer in proposing a magnetic survey of the North Pacific Ocean to the Carnegie Institution of Washington. This proposal was the inception of the project of the more extensive surveys of the oceans later executed by the *Galilee* and *Carnegie*. Littlehales was also consulting hydrographer of the Department of Terrestrial Magnetism of the Carnegie Institution during 1904-06. He gave much encouragement and support to Dr. Bauer in establishing this Journal, being one of its associate editors from its beginning in 1896 until 1909 and contributing several articles to the early volumes. Under the auspices of the Hydrographic Office he also issued a number of publications on terrestrial magnetism dealing chiefly with those aspects of the subject relating to navigation and cartography.

Mr. Littlehales represented the United States at various international scientific conferences and assemblies, among them the International Hydrographic Conference in London in 1919 when the International Hydrographic Bureau was inaugurated. He was a delegate to the Pan-Pacific Scientific Conference at Honolulu in 1920, the assemblies of the International Union of Geodesy and Geophysics at Rome,[1] 1922, and Stockholm, 1930, the Pan-Pacific Science Congress, Tokyo, 1926, and the International Congress of Oceanography, Marine Hydrography and Continental Hydrology, Seville, 1929.

Among the scientific societies of which he was a member, were the Washington Academy of Sciences, Philosophical Society of Washington, and the American Society of Naval Engineers. He took an active part in the activities of the American Geophysical Union, serving as its vice-president (1926-29), as chairman of its Section of Oceanography (1919-22), and as chairman of its Section of Meteorology (1929-32). He was also vice-president of the Section of Oceanography of the International Union of Geodesy and Geophysics (1921-32).

There stand to the credit of Mr. Littlehales more than 100 papers dealing with researches in hydrography, oceanography, and terrestrial magnetism and about 3,000 charts which were used in the navigation of the vessels of the world.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., August 14, 1943

[1]The portrait is from a photograph taken (April 1922) on the *Regina d'Italia* en route to the Rome Assembly of the International Union of Geodesy and Geophysics (courtesy of the Department of Terrestrial Magnetism).

REVIEWS AND ABSTRACTS

P. J. Nolan. *The recombination law for weak ionization.* Proc. R. Irish Acad., *A*, **49**, 67-90, 4 figs., 1 table (1943).

The principal object of this investigation was to determine whether the usual recombination-law—$(dn/dt) = (q - \alpha n^2)$—for ions in a pure gas, holds for small values of the ionization, q, such as are found in the lower atmosphere. A. D. Power appears to have been the only other investigator who has used such low values of q. The author recognizes the possibility that condensation-nuclei inside the ionization-chamber affect the results and accordingly used only well-filtered air and waited for a period of at least a week before making the first observation. Two methods of observation were followed. In the first, the gas within the chamber was exposed to a source of steady ionization (radium) sufficiently long for equilibrium-conditions to be established. The value, n, of the ionic-content of the gas was then determined. In the second method, all ions were removed from the gas and the rate at which the number of ions increased with time while under the influence of a steady ionizing source, was noted. By the latter method it was found that the above law applied over the whole range of q investigated. By the first method, deduced values of q were larger than those obtained by the latter method. This was presumably due to the lack of uniform distribution of ions (columnar ionization) inside the chamber in the case of the first method. For low values of q, the data in some cases seemed to support the first-power recombination-law—$(dn/dt) = (q - \beta n)$—for high field-values of q. It was not possible, however, to decide whether this relationship was real or only apparent. The mean value of α deduced from the experiments is 1.41×10^{-6} cc/sec and is found to be independent of ionic concentrations between 1,500 and 12,000 per cc.

In the opinion of the reviewer, the published results of many observers may be unreliable because condensation-nuclei were present in the enclosed gas. Condensation-nuclei in the gas alter the apparent value of α derived from a given set of data and at the same time, if sufficiently numerous, make the data appear to support the first-power instead of the second-power law. The effect of nuclei becomes increasingly pronounced as the ionization is diminished. It is to be hoped, therefore, that investigators may henceforth recognize the part played by condensation-nuclei as a destroying agency for small ions. Care must be taken to reduce to a minimum the number introduced into the chamber, to eliminate, as far as possible, all sources of nuclei within the chamber, and finally to provide an adequate measure of the number in the gas under examination. It is too seldom realized that the very source of ionization may be a source of condensation-nuclei.

Sayers points out that ozone is formed through the action of X-rays in air and through such action heavy ions (condensation-nuclei) are formed. He suggests the use of ultra-violet light as a source of ionization, in order to avoid columnar ionization. He apparently fails to realize that ozone and consequently condensation-nuclei may also be formed through the action of such light. It might be pointed out that according to recent experiments at the Department of Terrestrial Magnetism, the action of even radioactive matter appears to give rise to a limited number of intermediate ions. Only through the appreciation of these problems will it be possible to arrive at precise values of α, the recombination-coefficient of small ions.

G. R. Wait

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LETTERS TO EDITOR

(See also page 170)

SOLAR AND MAGNETIC DATA, APRIL TO JUNE, 1943, MOUNT WILSON OBSERVATORY

No magnetic storms were recorded in the second quarter of 1943, although active sunspot-groups (Mount Wilson Nos. 7571, 7573, 7578, and 7579) with bright chromospheric eruptions were present.

Although sunspot-groups of the new cycle have appeared, minimum sunspot-activity will probably not be reached for some months. The high-latitude groups Nos. 7579 and 7582 were certainly members of the new cycle.[1] Group 7532, which crossed the central meridian on December

[1]Pub. Astr. Soc. Pacific, **55**, 182 (1943).

20, 1942, probably belonged to the new cycle, although its polarities were like those of the waning cycle.[2]

[2]Pub. Astr. Soc. Pacific, **55**, 43 (1943).

Group 7581, which was a return of Nos. 7574, 7569, and 7559 had a continuous existence of at least 88 days. No. 7559 was a revival of No. 7550. Thus the area containing these groups was active during an interval of 112 days.

Table 1 (p. 187) summarizes the solar and magnetic data for the quarter from April to June, 1943.

April 1943

Day	K_2 Whole disk	K_2 Central zone	$H\alpha$ bright	$H\alpha$ dark	No. groups	Mag'c char.
1	2	1	2	1	3	0.5
2	2	1	2	1	3	0.5
3	2	1	2	1	3	0.5
4	2	2	2	1	3	0
5	..	..	..	..	2	0.5
6	..	..	..	..	..	0.5
7	1	2	1	1	1	0.5
8	..	..	..	..	..	0.5
9	..	..	..	..	2	0
10	..	..	..	..	..	0.5
11	1	0	1	2	2	0.5
12	..	..	..	..	2	0
13	1	1	2[c]	3	1	0
14	..	..	..	..	1	0
15	..	..	..	..	2[f]	0
16	2	2	2	1	3[b]	0.5
17	2	1	2	1	3	0
18	2	1	3	1	3	0
19	2	3	..	..	3	0
20	..	..	..	..	3	0
21	2	3	2[c]	1	2[g]	0.5
22	2	2	2	2	2	0
23	2	1	2	1	2	0
24	2	1	2[d]	2	2	0
25	1	1	1	1	2	0
26	1	1	1	1	2	0.5
27	1	1	1	1	2	0
28	1	1	1	1	1	0
29	1	1	1	1	2	0.5
30	1	1	2	1	1	0.5
31						
Mean	1.6	1.3	1.7	1.2	2.1	0.2

May 1943

Day	K_2 Whole disk	K_2 Central zone	$H\alpha$ bright	$H\alpha$ dark	No. groups	Mag'c char.
1	1	1	2	1	1	0.5
2	..	..	..	..	1	0.5
3	2	2	2	0	1	0
4	2	2	2	0	1	0
5	1	1	1	1	1	0
6	1	1	1	2	1	0
7	1	0	1	2	1	0
8	1	1	1	2	2	0
9	1	1	1	2	2	0
10	1	1	1	2	1	0
11	1	1	1	3	3	0
12	1	1	2[d]	3	2	0.5
13	1	1	1	2	2	0.5
14	2	1	2	2	2	0
15	2	1	2	1	2	0.5
16	2	2	2	1	3[b]	0
17	2	3	2[d]	1	3	0.5
18	2	3	2	0	3[f]	0.5
19	2	2	2	1	3	0.5
20	1	1	2	1	1	0
21	1	1	1	1	1	0
22	1	0	1	1	1	0
23	0	0	0	1	1	0
24	0	0	0	1	2	0.5
25	1	0	1	1	2	0.5
26	1	0	1	1	2	0
27	1	1	1	2	2	0
28	1	1	2	1	2	0.5
29	1	2	1	1	2	0.5
30	1	2	2	1	2	0.5
31	2	2	2	1	2	0
Mean	1.2	1.2	1.4	1.3	1.8	0.2

June 1943

Day	K_2 Whole disk	K_2 Central zone	$H\alpha$ bright	$H\alpha$ dark	No. groups	Mag'c char.
1	1	1	1	1	2	0
2	1	1	1	1	0	0
3	1	1	1	2	0	0
4	..	..	..	..	0	0
5	1	1	1	1	0	0
6	1	1	1	1	0	0
7	1	1	1	1	2	0
8	1	1	1	1	2	0.5
9	2	1	2	1	1	0.5
10	2	2	2	2	1	0.5
11	2	2	2	2	1	0
12	..	..	..	..	..	0.5
13	..	..	..	..	2	0.5
14	2	2	2	2	2	0.5
15	2	2	2	2	3	0
16	2	2	1	2	2	0
17	1	1	1	2	3	0
18	1	1	1	1	2	0
19	1	1	1	1	0	0.5
20	1	0	1	1	0	0.5
21	1	1	1	1	0	0.5
22	1	1	1	1	1	0.5
23	1	1	1	1	1	0.5
24	1	2	1	1	1	0.5
25	1	2	2	1	1	0.5
26	2	2	2	1	1	0
27	1	1	1	1	1	0
28	1	1	1	2	1	0.5
29	1	0	1	2	0	0
30	1	0	1	2	1	0
31						
Mean	1.3	1.2	1.3	1.4	1.1	0.2

NOTE—For an explanation of these tables see this JOURNAL, 35, 47-49 (1930).

The character-figures of solar phenomena are estimated from the spectroheliograms which are made with a 2-inch solar image, usually in the early morning. Very bright chromospheric eruptions are reported in these notes if observed at any time during the day.

[a], [b] Formation of a new group which later developed to average size or larger; (*a*) less than 30° from the center of the disk, (*b*) more than 30° from the center of the disk.

[c], [d] Very bright chromospheric eruptions; (*c*) less than 30° from the center of the disk, (*d*) more than 30° from the center of the disk.

[e], [f], [g], [h], [i], [j], [k], [l] Passage of a large or active group across the central meridian within 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40° of the center of the disk, respectively.

CARNEGIE INSTITUTION OF WASHINGTON,
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Pasadena, California

SETH B. NICHOLSON
ELIZABETH STERNBERG MULDERS

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory

April to June, 1943

(*Latitude 57° 03′.0 N., longitude 135° 20′.1 or $9^h\,01^m.3$ W. of Gr.*)

April 10-11—Beginning at $04^h\,30^m$ GMT, April 10, slight disturbances of all elements became greater three hours later and again increased in intensity at 11^h, but quieted rapidly after 13^h and continued with small variations until $03^h\,28^m$, April 11, when sudden increases in all elements commenced a nine-hour storm-period which was severe between $06^h\,25^m$ and 07^h when a *K*-index of 8 was recorded.

April 25-26—Sharp increases in traces at $02^h\,09^m$ GMT, April 26, were preceded by a gradual deviation from normal for three hours. Following a maximum of intensity about 06^h, lesser roughness continued until 13^h. *K*-indices of 7, 7, and 8 were recorded for the first three periods of April 26.

May 1-2—A severe storm began moderately at about $02^h\,30^m$ GMT, May 1, and reached a maximum of disturbance between 10^h and 11^h when a *K*-index of 9 was reached. Moderate disturbance continued during the following day. Portions of the storm were characterized by rapid oscillations of small magnitude.

Harold W. Pinckney, *Observer-in-Charge*

Cheltenham Magnetic Observatory

April to June, 1943

(*Latitude 38°.44′.0 N., longitude 76° 50′.5 or $5^h\,07^m.4$ W. of Gr.*)

April 2-3—A minor disturbance began at $23^h\,11^m$ GMT, April 2. The principal feature of the disturbance was a relatively deep bay in each of the three elements between 01^h and 02^h, April 3. A *K*-index of 6 was recorded during this period. After 08^h the activity was unimportant.

April 9-11—A disturbance began sharply at $20^h\,04^m$ GMT, April 9, but there was only negligible activity until about twenty-four hours later. From about 23^h, April 10, to 10^h, April 11, the disturbance could be regarded as a moderate storm. A *K*-index of 6 was recorded for the third three-hour period of April 11.

April 25-26—A moderate storm began very gradually at about 19^h GMT, April 25, and lasted about sixteen hours. A *K*-index of 6 was recorded for the third three-hour period of April 26.

May 1-2—Another moderate disturbance began at $02^h\,30^m$ GMT, May 1, and ended at about 11^h, May 2. Four *K*-indices of 5 were recorded.

May 15—A moderate storm began gradually at about 00^h GMT, May 15, and lasted for about twelve hours. Three *K*-indices of 5 were recorded.

May 17-19—A period of disturbance, not very severe but resulting in two *K*-indices of 6, began at approximately $13^h\,30^m$ GMT, May 17, and lasted until about 09^h, May 19. During the first ten hours the activity consisted almost entirely of very short-period oscillations with small amplitudes.

May 24—A bay giving a *K*-index of 6 in declination occurred during the first three-hour period of May 24.

June 7-10—A period of minor disturbance began very gradually at about 08^h GMT, June 7, and continued until the end of June 10. There were three K-indices of 5 during the period.

June 13—A bay in declination giving a K-index of 6 occurred during the first three-hour period of June 13.

June 19-20—A period of minor disturbance, which nevertheless yielded a K-index of 6, began very gradually at about 16^h GMT, June 19, and ended at about 06^h, June 20.

John Hershberger, *Observer-in-Charge*

Tucson Magnetic Observatory

April to June, 1943

(*Latitude 32° 14′.8 N., longitude 110° 50′.1 or 7^h $23^m.3$ W. of Gr.*)

April 2-4—A moderate storm began suddenly at 23^h 10^m GMT, April 2, with an increase of 23 gammas in H during the first five minutes. There was little outstanding activity and conditions were relatively quiet again by about 08^h, April 4. Ranges: D, 11′; H, 80 gammas.

April 10-11—A moderate storm began about 05^h GMT, April 10. The activity increased gradually and was greatest between 23^h, April 10, and 12^h, April 11. The disturbances ended rather suddenly about 13^h, April 11. Ranges: D, 15′.5; H, 112 gammas; Z, 33 gammas.

April 25-26—A moderate disturbance of comparatively short duration began about 21^h GMT, April 25, and ended about sixteen hours later. Ranges: D, 14′; H, 106 gammas; Z, 39 gammas.

April 30-May 2—A moderate storm began about 00^h GMT, April 30, and ended about 12^h, May 2. There seemed to be continuing minor variations in all elements, with little major activity. The relatively large range in H was provided by gradual changes (maximum and minimum values occurring thirty-eight hours apart) rather than by large swings on the trace. It was noted that the activity of D on the magnetogram seemed to be greater than usual as compared with H. Ranges: D, 15′.5; H, 125 gammas; Z, 43 gammas.

May 15—A moderate storm of duration only about twelve hours began about 00^h GMT, May 15. There were a few moderately large swings in D and H, and a slight disturbance in Z. Ranges: D, 17′; H, 98 gammas.

May 17-19—A storm of moderate intensity began gradually during the early part of May 17. Considerable activity of small amplitude and very short period began about 13^h GMT, May 17, and continued until about 02^h, May 18. Following this the disturbance was of larger amplitude and generally much longer period. The storm ended about 09^h, May 19. Ranges: D, 15′.5; H, 87 gammas; Z, 35 gammas.

June 8-9—A very mild storm began about 00^h GMT, June 8, with moderate disturbances of D and H continuing until about 15^h, June 9. Ranges: D, 13′.5; H, 87 gammas.

June 19-22—A series of moderate disturbances began about 16^h GMT, June 19. The larger variations ended about 09^h, June 22. The relatively disturbed magnetic "weather" continued until June 25, though after June 22 the disturbance was hardly of storm-intensity. Range: H, 119 gammas.

J. H. Nelson, *Observer-in-Charge*

Huancayo Magnetic Observatory

April to June, 1943

(Latitude 12° 02′.7 S., longitude 75° 20′.4 or 5^h $01^m.4$ W. of Gr.)

There were no magnetic disturbances worthy of description during the quarter. Paul G. Ledig, *Observer-in-Charge*

Apia Magnetic Observatory

April to June, 1943

(Latitude 13° 48′.4 S., longitude 171° 46′.5 or 11^h $27^m.1$ W. of Gr.)

There were no magnetic disturbances of any importance during the quarter. H. Bruce Sapsford, *Acting Director*

Magnetic Observatory, Hermanus

April to June, 1943

(Latitude 34° 25′.2 S., longitude 19° 13′.5 or 1^h $16^m.9$ E. of Gr.)

April 2-7—Disturbances began without conspicuous abruptness (H increased 14 gammas in ten minutes) at 21^h 05^m GMT, April 2. The disturbances continued until 21^h, April 7. The largest K-index value was 5 in the period 00^h-03^h, April 3.

April 10-12—Gradual-commencement disturbances began at 08^h GMT, April 10, and continued until 01^h, April 12. The period of greatest disturbance was from 18^h, April 10, to 06^h, April 11. The K-index values during this interval were 5, 4, and 5.

April 25-27—Gradual-commencement disturbances began at about 09^h GMT, April 25, and continued until 03^h, April 27. Bays of K-index value 5 were formed during the periods 03^h-06^h and 21^h-24^h, April 26

April 29-May 3—Disturbances began at 19^h GMT, April 29, and continued until 01^h, May 4. Bays of K-index value 5 developed during the periods 21^h-24^h, May 1 and May 3.

May 16-20—Disturbances which began at 09^h GMT, May 16, continued until 01^h, May 20. Bays of K-index value 5 were formed during the period 18^h-21^h, May 17.

May 24—Bays of K-index value 4 were formed during the periods 00^h-03^h and 03^h-06^h, and also 5 during the period 21^h-24^h, May 24.

June 7-9—Disturbances began at about 08^h GMT, June 7, and continued until 21^h, June 9. The maximum K-index value was 4 during the periods 15^h-18^h, June 8, and 09^h-12^h, June 9.

June 10—There were disturbances from 08^h to 24^h GMT, June 10. The maximum K-index value was 4 in the period 21^h-24^h, June 10.

June 13-28—Disturbances of K-index 4 were recorded during the periods, 00^h-03^h GMT, June 13 and June 20, 12^h-15^h, 15^h-18^h, and 21^h-24^h, June 23, and 18^h-21^h, June 28.

Micropulsations—There were micropulsations on all traces during the following periods GMT: 21^h 05^m-21^h 10^m, April 2; 05^h 20^m-06^h 10^m, April 20; 11^h 30^m-12^h 10^m, April 20; 00^h 20^m-01^h 30^m, May 6; 23^h 25^m-23^h 40^m, May 6; 02^h 25^m-02^h 55^m, May 7; 23^h 00^m-23^h 30^m, May 7; 01^h 50^m-02^h 05^m, May 10; 23^h 45^m, June 3-00^h 25^m, June 4; 23^h 15^m, June 5-00^h 25^m, June 6; 02^h 40^m-03^h 10^m, June 6; 23^h 40^m, June 19-00^h 25^m, June 20; 21^h 50^m-22^h 25^m, June 20; 21^h 35^m-22^h 00^m, June 21.

Hermanus, South Africa, July 2, 1943 A. Ogg, *Magnetic-Survey Adviser*

NOTES

16. *Repeat-stations in South America*—Joel B. Campbell and Fred Keller, Jr., of the United States Coast and Geodetic Survey, are proceeding with their magnetic observations in Brazil. Their program of work in Brazil has been greatly expanded.

17. *Magnetic survey and observatories of the United States*—Nathan O. Parker is continuing his field-work in the New England States and in the northern states east of the Rocky Mountains.

"Magnetic Observatory results at Sitka, Alaska, for 1933-34," one of the series of observatory-publications of the Coast and Geodetic Survey, has been released.

The old variation-observatory at the Tucson Magnetic Observatory has been removed. This building was erected in 1909 when the Observatory was established, but finally succumbed to the attacks of termites. It was replaced by a new building which is partially underground, this type of construction being feasible on the desert where ground-moisture is no problem.

18. *The magnetic compass and the Alcan Highway*—The magnetic compass, although now rarely used on the survey of an important project, was extensively employed in the location of the Alcan Highway (the highway from the United States through Canada to Alaska). Colonel Albert L. Lane, Corps of Engineers, U. S. Army, writing in the March 1943 number of *Civil Engineering* states that many methods were used in the forest covered and unsurveyed areas. They included: Low-flying airplanes steering by compass-course; compass-course with distance by strides; and in some cases bull-dozers steered for a distant point which was selected by compass-bearing.

19. *Local poles and anomalies in polar regions*—A local magnetic pole was found off Cape Lambton, south extremity of Banks Island (latitude 71° north, longitude 123° west) in fairly deep water according to V. Stefanson in "The friendly arctic" (p. 397).

A local anomaly equal to at least 8° in declination was found by Scott off the west shore of Ross Sea, north of Ross Island. This is significant because it is in the general region of the south magnetic pole. It may be that the ice-sheet at the pole tends to smooth out anomalies. (See "Voyage of the *Discovery*," **1**, p. 147.)

The action of a compass near the north magnetic pole is described in an article in the *Geographical Journal* (Royal Geographic Society). With reference to a ship in the Coronation Gulf, it was stated, "When the ship left the shelter of the ice it grew very rough, a fog descended and when the Sun was seen a few hours later it was found that the ship was turned around and was sailing back into Coronation Gulf. Compass cannot be relied on sò near the north magnetic pole."

20. *Geophysical observations in the region of the new Mexican volcano*—Ralph R. Bodle and Nelson C. Steenland have recently returned to

Washington from their work in connection with the recently formed Paracutin Volcano in the State of Michoacan, Mexico. This project was sponsored by the United States Department of State in cooperation with the Government of Mexico. A magnetic vertical-intensity survey, with stations spaced about one km apart, was made of the area within 25 km of the new volcano which was formed on February 20, 1943. Three complete magnetic stations were established for the purpose of repeat observations at some future date.

A seismograph was also operated for seven weeks at Uruapan to register local shocks and to determine the feasibility of renewing the project on a larger scale at some future time. The Pan-American Institute of Geography and History (Dr. Pedro Sanchez, Director) was the cooperating agency of Mexico and assistance was rendered by Dr. Joaquín Gallo, Director of the National Astronomical Observatory at Tacubaya. In July the party was visited and the work inspected by Commander Otis W. Swainson, Chief of the Section of Geomagnetism and Seismology of the United States Coast and Geodetic Survey.

21. *Chree Medal and Prize for 1943*—Referring to our note on page 79 of the present volume of the JOURNAL, we have now learned that the presentation of the Medal and Prize was made to Professor (now Brigadier) Basil F. J. Schonland at the meeting of the Physical Society at the Royal Institution on July 16, 1943, when Brigadier Schonland delivered the second Charles Chree Lecture, taking as his subject "Thunderstorms and their electrical effects."

22. *Personalia*—The King's Birthday Honors List of June 1, 1943, contains the name of Dr. *H. Spencer Jones*, F.R.S., Astronomer Royal, who becomes a Knight Bachelor. Our warm congratulations to Sir Harold for this well-merited honor.

George Washington Littlehales, Hydrographic Engineer (1900-32) of the United States Hydrographic Office, died August 12, 1943, at the age of 82 (see pp. 183-184).

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Cape Town. Results of observations made at the Magnetic Observatory of the University of Cape Town. Under the Direction of A. Ogg, Magnetic Survey Adviser. Trigonometrical Survey Office, Department of Lands, Union of South Africa. Pretoria, Govt. Printer, 151 pp. with numerous sheets of reproductions of curves. (1939). 32 cm. [Contains results of magnetic observations for 1933, 1934, 1935, and 1936.]

Chapman, S. Archaeologica geomagnetica—II. Terr. Mag., **48**, No. 2, 77-78 (1943)

Egypt, Physical Department. Meteorological report for the year 1936. Cairo, Ministry of Public Works, Physical Dept., xiv+252 (1942). 32 cm. [Contains values of the magnetic elements at Helwan Observatory for 1936.]

Fleming, J. A., and W. E. Scott. List of geomagnetic observatories and thesaurus of values. Terr. Mag., **48**, No. 2, 97-108 (1943). [First installment.]

Harradon, H. D. Some early contributions to the history of geomagnetism—II and III. (II) Treatise on the sphere and the art of navigation, by Francisco Falero; (III) Brief compendium on the sphere and art of navigating, by Martin Cortes. Terr. Mag., **48**, No. 2, 79-91 (1943).

Herroun, E. F., and A. F. Hallimond. Laboratory experiments on the magnetization of rocks. Proc. Phys. Soc., **55**, No. 309, 215-221 (1943). [Specimens of natural rock masses collected by H. M. Geological Survey were tested for magnetic susceptibility and permanent magnetization before and after various artificial treatments. After cooling in the Earth's field, cut cubes were found to be magnetized with an intensity much greater than that of the natural rock, and the values decayed very little with time. When artificially magnetized in the cold, the cubes were only affected by fields above a certain value, and the decay was often considerable. Curves are given showing the decay with time and the demagnetization of the heated cubes by increasing fields. The susceptibility of natural rocks increases with the field, in some cases reaching a maximum between 50 and 100 c. g. s. The results are compared with data by J. G. Koenigsberger.]

Institute of Terrestrial Magnetism U. S. S. R. Isogonic lines for epoch 1943. World chart. Scale 1:50,000,000 at 30° parallel. 53 x 79 cm. Moscow (1942). [In the construction of this chart, the results of ten years' work on general magnetic surveys were used for the territory of the U. S. S. R. Accordingly the chart for that part of the world is exceptionally accurate. For the remainder of the chart foreign material was used.]

Johnston, H. F. American magnetic character-figure, C_A, three-hour-range indices, K, and mean K-indices, K_A, for January to March, 1943. Terr. Mag., **48**, No. 2, 93-96 (1943).

Knapp, D. G., and H. H. Howe. Magnetic observatory results at Sitka, Alaska, for 1933-34. Washington, D. C., U. S. Coast Geod. Surv., 118 pp. (1942). 25 cm.

N., H. W. Magnetic storms and solar activity, 1942. Observatory, **65**, No. 813, 31-32 (1943).

PRINCIPAL MAGNETIC STORMS. Principal magnetic storms, January to March, 1943. Terr. Mag., **48**, No. 2, 117-122 (1943).

UNITED STATES COAST AND GEODETIC SURVEY. Lines of equal magnetic declination and annual change, 1942, Caribbean Sea. Washington, D. C., U. S. Coast Geod. Surv., scale 1:5,000,000, 63 x 110 cm. (1943). [Based upon field-observations made by the United States Coast and Geodetic Survey in 1941 and 1942 in cooperation with the Department of State and the American Republics in the area and upon field-observations by the Mexican Government.]

WALDMEIER, M. Coronal intensity and geomagnetism. (Zs. Astroph., **21**, 275-285, 1942). [The appearance at the Sun's limbs of "*C*-regions" of abnormal intensity of the coronal line 5303 Å is correlated with the occurrence about 7.4 days later (E. limb) or 6.2 days earlier (W. limb) of geomagnetic disturbances. The phenomena are associated in 10 out of 15 cases of observed coronal activity at the limb. On the assumption that all *C*-regions cause magnetic activity on passing the central meridian, this gives them a lifetime of 24 days. Coronal observations were possible at the appropriate times for 10 out of 20 magnetic storms in 1939 and 1940; in 7 cases *C*-regions could be associated with the storms, in 3 no such association is possible. This agrees with the lifetime previously found and suggests that in all 10 storms were associated with the central meridian passage of *C*-regions. The *C*-regions are not associated with photospheric disturbances, though they appear only in the spot-zones. It is suggested that they are identical with the *M*-regions postulated to account for periodic magnetic storms by long-continued corpuscular emission. Sci. Abstr., A, **46**, No. 546, 107 (1943).]

B—Terrestrial and Cosmical Electricity

CARMICHAEL, H. The aurora. Polar Record, **4**, No. 25, 12-16 (1943). [Based mainly on "A survey of the facts and theories of the aurora," by E. W. Hewson, Rev. Modern Phys., **9**, 403-431 (1937).]

COCCONI, G., A. LOVERDO, UND V. TONGIORGI. Ueber das Vorhandensein von Mesotronen-Schauern in den ausgedehnten Luftschauern. Naturwiss., **31**, Heft 11/13, 135-136 (1943).

GREISEN, K. Intensity of cosmic rays at low altitude and the origin of the soft component. Phys. Rev., **63**, Nos. 9 and 10, 323-333 (1943).

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MILLIKAN, R. A., H. V. NEHER, AND W. H. PICKERING. Origin of cosmic rays. Nature, **151**, 663-664 (June 12, 1943).

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ROSEBRUGH, D. W. "Swish" of the aurora. J. R. Astr. Soc. Canada, **37**, No. 6, 254-255 (1943).

SIMPSON, G. C. The separation of electricity in clouds. Phil. Mag., **34**, No. 231, 285-287 (1943). [Remarks on article of the same title by J. Alan Chalmers in Phil. Mag., **34**, No. 228, 63-67 (1943).]

SWANN, W. F. G. The variation of mesotron intensity with altitude and latitude, together with allied phenomena, and the bearing of these matters on the nature of the primary particles. Part I. J. Frank. Inst., **236**, No. 1, 1-7 (1943).

TABIN, J., AND M. SCHEIN. Measurements of cascade showers produced by ionizing and non-ionizing radiation in the stratosphere. Abstract, Phys. Rev., **63**, Nos. 11 and 12, 462 (1943).

WOLF, F. Das Gewitter und seine Entladungsformen. II. Teil: Kugelblitze und Perlschnurblitze. Naturwiss., **31**, Heft 19/20, 215-223 (1943).

ZINSZER, R. H. The use of electrode spacing in well logging. Amer. Inst. Min. Metall. Eng., Tech. Paper No. 1590, 10 pp. (1943).

C—Miscellaneous

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